Introduction to the Hazard Analysis

This hazard analysis section has been completely updated from the previous 2011 edition of the Michigan Hazard Mitigation Plan. The advancements made in the 2012 Michigan Hazard Analysis have been incorporated in this updated 2014 document and supplemented with additional new material. This section provides a comprehensive update of all the material that had previously appeared in the Michigan Hazard Analysis, but it also includes additional detail about —one on Catastrophic Incidents (National Emergencies) and another on Celestial Impacts. The Catastrophic Incidents section has been added, in part, to better tie in with similar concepts being addressed in the Michigan Emergency Management Plan, and other documents and recommendations at the federal level. These changes make the plan not only compliant with FEMA planning standards, but with larger EMAP standards as well, with a full consideration of natural hazards, technological hazards, human-related hazards, as well as greater linkages between hazard mitigation and the other phases of emergency management—preparedness, response, and recovery.

In order to make such a large array of hazards more comprehensible, they have now been reorganized so that the most closely-related hazards are located near each other in the same section of this plan (instead of the alphabetical arrangement that had been used previously). There is extensive overlap between natural hazards. Similarly, technological hazards and human-related hazards tend to share a great deal in common with each other. Therefore, the hazard analysis component of this plan now includes three major divisions that correspond to these three major hazard classifications. Each of these three major sections has been further organized so that readers and responders can more easily find information about hazards that are closely related to each other. Persons who need information about weather hazards, for example, do not need to switch between sections separated by hundreds of pages, but instead can refer specifically to a single section of this plan.

This reorganized hazard analysis begins with a section on **natural hazards**. It makes sense to list these hazards first, because they so commonly affect Michigan. There is not a single part of Michigan that isn't susceptible to severe weather, for example. Within the natural hazards section, weather hazards have been listed first. Most of the weather hazards subsection deals with violent weather events such as thunderstorms and tornadoes, but there is also an entire component that addresses hazardous winter weather. One of the weather-related hazards, extreme temperatures, addresses both summer and winter weather issues in one section.

Many weather hazards affect the hydrological conditions in Michigan and its local communities, and therefore the weather hazards section is immediately followed by a section dealing with hydrological hazards—flooding and drought. The flood hazard section includes three major components—inland (riverine) flooding, Great Lakes shoreline hazards, and dam failures. The shoreline hazards component not only includes information about flooding, but other topics relevant to coastline areas along the Great Lakes—storm surges (seiches), rip currents, Great Lakes water recession, and shoreline erosion.

The first two natural hazard subsections flow well into a consideration of Michigan's two main ecological hazards—wildfires and invasive species. Both weather and hydrological conditions affect Michigan's ecological conditions, and its vulnerability to wildfires and invasive species. The natural hazards section wraps up with a subsection on Michigan's geological hazards. Although these are not insignificant, they tend not to pose as much direct risk to Michigan as the other types of natural hazards. This plan now includes a section titled "Celestial Impact," which considers such issues as solar storms that have the potential to disrupt important infrastructure, and the impact or threatened impact of physical bodies upon the Earth's land, sea, or atmosphere, the latter of which is rare as a hazard but has the potential for impacts that are truly catastrophic. These issues are here treated for the first time in State-level planning, and are given a realistic assessment (which can offset some of the alarmist media presentations that have appeared in recent years).

The **technological hazards** section includes two major subsections—one dealing with industrial hazards and the other with infrastructure problems. Within the industrial hazards subsection are components dealing with fires, hazardous materials incidents of various kinds, nuclear power plant issues, and accidents involving Michigan's oil and gas pipelines and wells. Within the subsection on infrastructure problems are components dealing with various forms of infrastructure failure, energy emergencies, and major transportation accidents.

The final major section of the hazard analysis, **human-related hazards**, contains five components, including a new consideration of the general topic of catastrophic incidents (national emergencies). In the past decade, major national incidents involving terrorism and hurricanes have made it clearer than ever how interconnected we all must be. We as a state experience both direct and indirect effects from events that take place elsewhere in the nation and the world. This new component of the hazard analysis provides an overview of events, such as 9/11 and Hurricanes Katrina and Rita, whose scale may necessitate extensive activities within Michigan even though the direct impacts of the event primarily occurred outside of our state. The section on civil disturbances has been extensively rewritten, to add additional information from social science research. Similarly, the section on nuclear attack has also been rewritten, to better reflect the new post-Cold War era in which the role of terrorist nuclear threats is of even greater concern. This is followed by an updated section on public health emergencies, which includes new information about the threat of pandemics, and the final section on terrorism has, like the nuclear attack section, been almost entirely rewritten, to better reflect the current geopolitical situation, as well as advances in our understanding of the threat, as informed by recent events and new research in homeland security studies.

The result of these changes is meant to be a document that is much more comprehensive, up-to-date, and valid than has appeared in any previous state plans, while also being easier to use. It is worth noting that many of the sources used in previous documents that provided an informational background for this plan were not always cited in a manner that allowed them to remain clearly connected with the material in this updated plan as that material was adapted for use here. Although this information was all reviewed and, in many cases, double-checked, the sources cited in this plan tend to only be ones used for the new material that was added to this plan. Citations for text adapted from earlier documents (e.g. the 2006 edition of the Michigan Hazard Analysis) might be tracked down through those earlier documents, but many government documents have differed over the years from academic documents, in the precision and consistency of citation use. Due to the large number of events described in lists throughout this document, the decision was made not to provide citations for every item. Some of the sources used are not ones that allow verification by most readers (such as LEIN messages, Flash Reports, local hazard mitigation plans, internal MSP documentation from disasters, and emergency management correspondence). If there is a question about any of the information in this document, inquiries can be directed to Mike Sobocinski at (517) 336-2053 (or sobocinskim@michigan.gov) and the information can then be double-checked or its basis explained. Amidst some internal discussion, there have been some references to the Wikipedia online encyclopedia included—not as a final information source, but to give it credit as providing a handy gateway to identifying numerous articles and internet sources whose validity was then judged and then considered for use as an authoritative source. For example, many of the Wikipedia entries led to articles that had originally appeared in peer-reviewed scientific journals.

One final note may also be helpful regarding the sometimes lengthy lists of historical incidents included in this plan. Some of the rarer types of incidents may use examples from outside of Michigan, when it was felt that an insufficient number or variety of Michigan examples was available, or because they involved scenarios that in some manner were deemed to be noteworthy for an analysis of that hazard. On the other hand, lengthy lists of Michigan examples have been provided for other hazards—often with a reduced font size. These lists sometimes contain specific local information, and are intended to help provide links between this state level plan and plans at the local level. The inclusion of some specific local information can be helpful in the development and update of local hazard mitigation plans, just as the review and consideration of local plans has been helpful for this update of the latest State plan. Readers may scrutinize or skim over those sections as they like, but this plan has been revised from the perspective that the best means of analyzing hazards is to maintain a solid historical grounding.

With an introductory overview now provided to readers, an outline of the full hazard analysis section is hereby presented, as a quick guide to the hundreds of pages that follow:

I. Natural Hazards
- A. Weather Hazards
  - 1. Storms
    - a. Thunderstorms, including hail and lightning
    - b. Winter storms, including ice, sleet, and snow
  - 2. Severe winds
  - 3. Tornadoes
  - 4. Extreme temperatures
  - 5. Fog
- B. Hydrological Hazards
  - 1. Flooding
    - a. Riverine flooding
    - b. Great Lakes shoreline hazards
    - c. Dam failures
  - 2. Drought
- C. Ecological Hazards
  - 1. Wildfires
  - 2. Invasive species
- D. Geological Hazards
  - 1. Ground Movement
    - a. Earthquakes
    - b. Subsidence
  - 2. Celestial Impacts

II. Technological Hazards
- A. Industrial Hazards
  - 1. Fires
    - a. Structural fires
    - b. Scrap tire fires
  - 2. Hazardous Materials Incidents
    - a. Hazardous materials incidents – fixed site (including industrial accidents)
    - b. Nuclear power plant emergencies
    - c. Hazardous materials incidents – transportation
    - d. Petroleum and natural gas pipeline accidents
    - c. Oil and natural gas well accidents
- B. Infrastructure Problems
  - 1. Infrastructure failures
  - 2. Energy emergencies
  - 3. Transportation accidents (air, rail, highway, marine)

III. Human-Related Hazards
- A. Catastrophic incidents (national emergencies)
- B. Civil disturbances
- C. Nuclear attack
- D. Public health emergencies
- E. Terrorism and similar criminal activities (including cyber-attacks)

Information about these hazards is summarized in the following table. Note that some entries in this table are based upon a limited analysis and therefore should be treated merely as rough estimates.

Hazard Analysis Summary Table

	Average annual events	Average annual deaths	Average annual injuries	Average annual property damage	Development trend effects	Risk rating: casualties	Risk rating: property	Risk Rating: economic costs	Risk rating: Infrastructure effects	Risk rating: Environment	Frequency as a top local hazard
Hail	**~25**	**0.0**	**0.0**	**$15 million**	+	**0**	**2**	**2**	**1**	**1**	**Some**
Lightning	**~12**	**1.5**	**10.7**	**$1.4 million**	=	**1**	**1**	**2**	**2**	**2**	**Some**
Ice and sleet storms (damage estimate includes snowstorms)	**2.2**	**>1**	**>1**	**~$12 million**	+	**1**	**2**	**3**	**3**	**1**	**Some**
Snowstorms	**>1**	**>1**	**>1**	(included above)	+	**1**	**1**	**2**	**2**	**1**	**Many**
Severe winds	**~8**	**2**	**20**	**~$25 million**	+	**1**	**2**	**3**	**3**	**1**	**Many**
Tornadoes	**~16**	**4**	**60**	**$17.8 million**	+	**2**	**2**	**3**	**3**	**2**	**Many**
Extreme heat	**~7**	**2?**	**?**	**?**	=	**2**	**0**	**2**	**2**	**0**	**Some**
Extreme cold	**~30**	**5?**	**?**	**$millions**	=	**2**	**2**	**3**	**3**	**1**	**Some**
Fog	**0.5**	**?**	**?**	**?**	+	**1**	**0**	**1**	**1**	**0**	**None**
Flooding	**>1**	**0.4**	**0.5**	**~$80 million**	+	**1**	**2**	**3**	**3**	**2**	**Some**
Shoreline hazards	**>1**	**~2**	**~4**	**>$10 million**	+	**1**	**2**	**3**	**2**	**1**	**Some**
Dam failures	**~2?**	**0?**	**0?**	**$thousands**	+	**2**	**2**	**3**	**2**	**2**	**Some**
Drought	**0.5**	**0**	**0**	**$millions**	?	**0**	**0**	**3**	**1**	**2**	**Few**
Wildfires	**>550**	**3.7**	**?**	**~$1 million +**	+	**2**	**2**	**3**	**2**	**3**	**Some**
Invasive species	**?**	**?**	**>1**	**$millions**	?	**1**	**2**	**3**	**1**	**3**	**None**
Earthquakes	**0.3**	**0**	**0**	**$165,000**	+	**1**	**1**	**2**	**2**	**2**	**Few**
Subsidence	**0.4**	**0**	**0**	**mere thousands?**	+	**1**	**1**	**1**	**1**	**1**	**Few**
Celestial impacts (impacting object)	**<1**	**0**	**0**	**<$1,000**	+	**0**	**1**	**1**	**1**	**1**	**None**
Celestial impacts (space weather)	**~0.3**	**0**	**0**	**$millions?**	+	**0**	**1**	**2**	**2**	**0**	**None**
Structural fires (major)	**>1**	**>5**	**>10**	**>$many millions**	-	**2**	**2**	**2**	**1**	**2**	**Few**
Scrap tire fires	**0.5**	**0**	**0**	**$thousands**	=	**0**	**1**	**2**	**1**	**2**	**Few**
Hazardous materials incident (fixed site)	**~7**	**>1**	**>1**	**$millions**	+	**2**	**2**	**2**	**2**	**2**	**Some**
Nuclear power plant	**0.02**	**0**	**0**	**0**	+	**0**	**1**	**2**	**2**	**2**	**Few**
Hazardous materials (transportation)	**~13**	**>1**	**>1**	**$many thousand**	+	**2**	**2**	**2**	**2**	**2**	**Some**
Oil & gas pipelines	**>1**	**~0.7**	**~1.4**	**$millions**	+	**1**	**2**	**2**	**2**	**2**	**Few**
Oil & gas wells	**0.2**	**<1**	**<1**	**?**	+	**1**	**1**	**1**	**1**	**1**	**Few**
Infrastructure failures	**>1**	**<1**	**<1**	**$many millions**	+	**1**	**1**	**3**	**3**	**2**	**Some**
Energy emergencies	**~1**	**0**	**0**	**?**	+	**0**	**0**	**2**	**2**	**1**	**None**
Transportation accidents (major)	**>1**	**>1**	**>1**	**$many thousands**	+	**2**	**1**	**2**	**1**	**1**	**Few**
Catastrophic incidents	**<1**	**>1**	**>1**	**?**	=	**1**	**0**	**2**	**2**	**2**	**None**
Civil disturbances	**<1**	**>1**	**>1**	**$thousands**	=	**2**	**2**	**2**	**1**	**1**	**Few**
Nuclear attack	**0**	**0**	**0**	**?**	-	**2**	**2**	**2**	**2**	**2**	**Many**
Public health emergencies	**?**	**>1**	**>1**	**?**	-	**2**	**0**	**2**	**2**	**1**	**Few**
Terrorism and similar activities	**<1**	**>1**	**>1**	**?**	=	**2**	**2**	**2**	**2**	**2**	**Some**

"**Average annual**" numbers are medium-term estimates only. Medium-term means that most estimates were based upon decades' worth of data, to predict future decades' risk. Numbers that could not be validly determined are marked "?"

Development trend effects use the following symbols to estimate the effects from Michigan's recent land use trends (which still mainly involve the construction of suburban, exurban, and rural detached homes for persons moving out of denser areas). "+" means increasing risks, "=" means few net effects, "-" means decreasing risks, "?"means trends are unclear

Risk Ratings are based upon the estimated severity of average annual impacts (medium-term), as follows:

"0" means negligible: The risks as currently known are not likely to cause any emergency-level event.

"1" means minor: There is a known although infrequent chance for impacts of moderate or purely local severity.

"2" means significant: A regular pattern of moderate effects, or an infrequent chance of severe impacts.

"3" means major: A regular pattern or high risk of major impacts, of statewide significance.

"**Frequency as a top local hazard**" refers to the number of local plans listing this as one of their top hazards. Categories include "Many," "Some," "Few," and "None." Note that because FEMA requires the analysis of natural hazards, but not technological and human-related hazards, local plans are inclined to favor the listing of natural hazards.

I. Natural Hazards
A. Weather Hazards

The following outline summarizes the significant weather hazards covered in this section:

1. Storms
    a. Thunderstorms, including hail and lightning
    b. Winter storms, including ice, sleet, snow
2. Severe Winds
3. Tornadoes
4. Extreme Temperatures
5. Fog

These weather hazards can be thought of in general terms, according to whether they involve winter weather conditions or not. The winter storms section, and half of the extreme temperatures section, should be referred to for a good overview of Michigan's winter weather hazards. The other sections focus upon weather conditions that predominate in the non-winter months. However, it must be admitted that fog and strong winds may be present during the winter season as well, (although the strongest winds in Michigan usually occur during transition periods between warm and cool weather, and in association with severe thunderstorms). Strong winter winds may occur in conjunction with sleet and ice, and are a specific part of blizzard events, all described in the winter weather section. When ice and sleet have already weakened an area's tree limbs, power lines, and infrastructure, winter winds are often the final straw that causes tree limbs (or entire trees) to topple across roads or utility lines, causing life-threatening infrastructure breakdowns during periods of extreme cold. A big part of why this updated analysis now addresses all weather hazards within a single section is because there may not always be neat and precise distinctions between the different events. It makes sense to study these related topics together and then consider areas of overlap and similarity. But the most essential aspects of Michigan's winter weather hazards are described in the two sections: winter storms and extreme temperatures.

The non-winter months usually see the other types of severe weather hazards—thunderstorms and tornadoes, lightning and hail, and extreme heat. Thus, most of this section of the hazard analysis describes hazards that regularly occur during the non-winter months. The seasons in Michigan do not completely match those seen on the standard calendar, and they vary a little bit depending upon the area of the State being considered. As will be described further in the material on each hazard, Michigan's weather is affected by its location in the middle of the Great Lakes. Locations next to, or distant from, a Great Lakes shoreline, will often have different weather patterns and hazard risks. There is also a general trend relating to how far to the north the area under consideration is located. Michigan may be thought of in terms of three broad geographic divisions: the Upper Peninsula, the Northern Lower Peninsula, and the Southern Lower Peninsula. The Upper Peninsula, in addition to containing the northernmost locations and the areas of highest elevation (e.g Mount Arvon in Baraga County, at 603m), also has areas that are more exposed to weather patterns blowing in from the west, without the extent of moderating Lake Michigan influence enjoyed by the Lower Peninsula. This exposes the Upper Peninsula to colder average temperatures and longer winters. The Lower Peninsula contains a northern region that contains large areas of woodland, as well as areas of hilly landscape and higher elevation (e.g. Grove Hill, in northern Osceola County, at 522m) than its southern region, in which agricultural and urban land uses are predominant.

Although three general Michigan regions each have different degrees of risk and vulnerability from weather hazards, it is important to note that <u>all</u> of them are at-risk from each of the hazards in this section. The risks merely vary by the probability of the worst impacts, and the degree and severity of the "typical" impact. Every one of Michigan's 83 counties has experienced severe thunderstorms and at least one confirmed tornado. Every county is also susceptible to strong winds, extreme temperatures, and severe winter weather. The variation across Michigan is primarily one of likelihood and the range of intensity.

Therefore, for the weather hazards, it may make sense to think in terms of two parts of the year: winter and non-winter. Although mild snowfall and cold temperatures may occur a little bit outside of the main period of wintry weather, such events tend not to be serious ones, and therefore a general distinction can be made between the "winter weather risk season" and the "non-winter weather risk season." The winter weather risk season is defined in terms of historically documented events involving extreme cold and significant snowstorms. Seasons of winter weather risk include months during which record low temperatures are near enough to zero to make it likely that wind chill advisories would be issued, and when record snowfall levels have amounted to several inches. Even if these events are less likely on the "edges" of the season, since they have occurred, it made sense to define risk periods in terms of these possibilities. On the flip side, all the other months are susceptible to extreme heat (months in which record high temperatures go above 90 degrees Fahrenheit and thus make it likely that a heat advisory might need to be issued.

On the basis of this historical analysis, it was determined that the risk periods for extreme temperature and snowfall events can be assigned to the following months, for Michigan's three general regions. (NOTE: Do not use these seasons to define severe wind risks. For example, strong tornadoes have occurred in months such as October and April.)

1. Southern Lower Peninsula:	Winter risk season from late November to early April Non-winter risk season from early May to late September

(extend that last risk season to early October for the southernmost tiers of counties, such as Berrien and Wayne)

2. Northern Lower Peninsula:	Winter risk season from early November to April Non-winter risk season from late May to late September
3. Upper Peninsula	Winter risk season from Late September to May Non-winter risk season from late May to early September

Some variation may be expected between counties, especially shoreline counties that observe the tempering effect of the Great Lakes, but these may be good "rules of thumb" for the times of the year when different types of weather risks will occur in different parts of Michigan. The extreme heat hazard, for example, will affect the Upper Peninsula for a somewhat shorter time period each year than it does the Southern Lower Peninsula. However, this difference does not change the fact that once the risk season has arrived, both areas are at risk. In July, for example the City of Ironwood has recorded a record high temperature of 103 degrees, and although the record high temperatures in the Southern Lower Peninsula have reached 108 degrees, the all-time highest recorded temperature in Michigan actually came from the Northern Lower Peninsula, when Oscoda County hit 112 degrees (although the major weather stations at other locations across the region report records of 106 degrees). Thus, although there are differences and trends between regions and within them, the fact that all have experienced extreme heat waves must be recognized. In other words, the commonalities shared by Michigan's regions are more important than the differences, when it comes to weather-hazard preparedness and mitigation.

Historic Precipitation and Snowfall Records at Various Michigan Locations

Southern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Adrian (Lenawee County)	4.74” (Sept. 3)	15.0” (Jan. 26)
Benton Harbor (Berrien County)	6.60” (May 30)	25.0” (Dec. 6)
Coldwater (Branch County)	5.37” (June 26)	17.0” (Jan. 26)
Ann Arbor (Washtenaw County)	4.54” (Aug. 6)	15.8” (Dec.1)
Bloomingdale (Van Buren Co.)	9.78” (Sept. 1)	20.0” (Dec. 10)
Detroit (Wayne County)	4.74” (July 31)	24.5” (April 6)
Jackson (Jackson County)	5.31” (June 21)	16.0” (March 17)
Pontiac (Oakland County)	4.75” (Oct. 1)	18.0” (Dec. 2)
Flint (Genesee County)	6.04” (Sept. 10)	14.5” (Jan. 26)
Grand Rapids (Kent County)	4.22” (June 5 & Aug. 19)	16.1” (Jan. 26)
Port Huron (St. Clair County)	3.97” (Sept. 7)	14.3” (March 27)
Harbor Beach (Huron County)	6.04” (Sept. 10)	18.0” (Feb. 21)
Big Rapids (Mecosta County)	7.64” (Sept. 11)	16.0” (Jan. 30)

The counties listed above start with the southernmost tier in Michigan, and proceed generally northward, tier by tier.

Northern Lower Peninsula	**Record Precipitation**	**Record Snowfall**
Alpena (Alpena County)	5.14” (Sept. 3)	18.2” (Feb. 22)
East Tawas (Iosco County)	3.72” (Aug. 16)	20.0” (Feb. 14)
Gaylord (Otsego County)	5.00” (Aug. 17)	20.0” (Nov. 23)
Gladwin (Gladwin County)	5.00” (May 20)	15.0” (Dec. 11)
Traverse City	4.30” (Aug. 23)	16.0” (Jan. 25 & Nov. 29)
Upper Peninsula	**Record Precipitation**	**Record Snowfall**
Hancock (Houghton County)	3.58” (May 17 & Sept. 4)	26.5” (Jan. 18)
Ironwood (Gogebic County)	6.72” (July 21)	24.0” (Dec. 16)
Munising (Alger County)	3.51” (May 31)	20.0” (March 15)
Sault Ste. Marie (Chippewa Co.)	5.92” (Aug. 3)	26.6” (Dec. 10)

Source: Extreme Michigan Weather, by Paul Gross (2010, University of Michigan Press, Ann Arbor)

For more information about the assessment of rainfall events (which can cause flash flooding), please refer to the precipitation-related information contained at the end of Attachment A, starting on page 705.

NOTE: In addition to numerous sources already referenced* in previous editions of this plan, the update and newly added text for this 2014 Michigan Hazard Mitigation Plan has benefited greatly from the following printed books:

Michigan Geography and Geology, edited by Randall Schaetzl, Joe Darden, and Danita Brandt. Pearson Custom Publishing, New York, et al., 2009.

Natural Disasters and How We Cope, chief consultant Robert Coenraads. Millenium House, Elanora Heights Australia, 2006. Used to expand information in numerous hazard analysis sections.

Secrets & Lies: Digital Security in a Networked World, by Bruce Schneier. Wiley Publishing, Inc. paperback edition: 2000, 2004. Used to expand the cyber-security information.

Additional sources from government documents, news articles, and internet sites will be provided later in this document.

* Note: A huge array of newspaper articles, web sites, government documents, official records, and books of all types have formed the basis of the information in this document. However, since previous editions did not connect each source with its corresponding text, there has not been a clear way to amend this document’s bibliography to correspond with the extensive changes that have been made over the years. Some sources used in earlier documents are expected to be out of date, and some of them were never listed when the 2006 update of the Michigan Hazard Analysis was published. Therefore, although the authors are confident in the quality of the information here, much of this edition does not attempt specific citations.

Overlap Between Weather Hazards and Other Sections of the Hazard Analysis

Extreme summer heat can increase the chances of wildfires (which has its own chapter in the "Ecological Hazards" section of this plan). Weather events involving precipitation have effects upon local hydrology. Heavy precipitation, and/or melting snow, can cause flooding. Ice jams and log jams (a source of which may include woody debris toppled into drains and streams by strong winds) can also cause flooding. For more information about flooding, please refer to the sections on Riverine and Shoreline flooding in the next section of this hazard analysis, dealing with "Hydrological Hazards." Also in the hydrological section is a chapter on droughts, which also have their origin in weather, but stem from experiencing too little precipitation rather than too much.

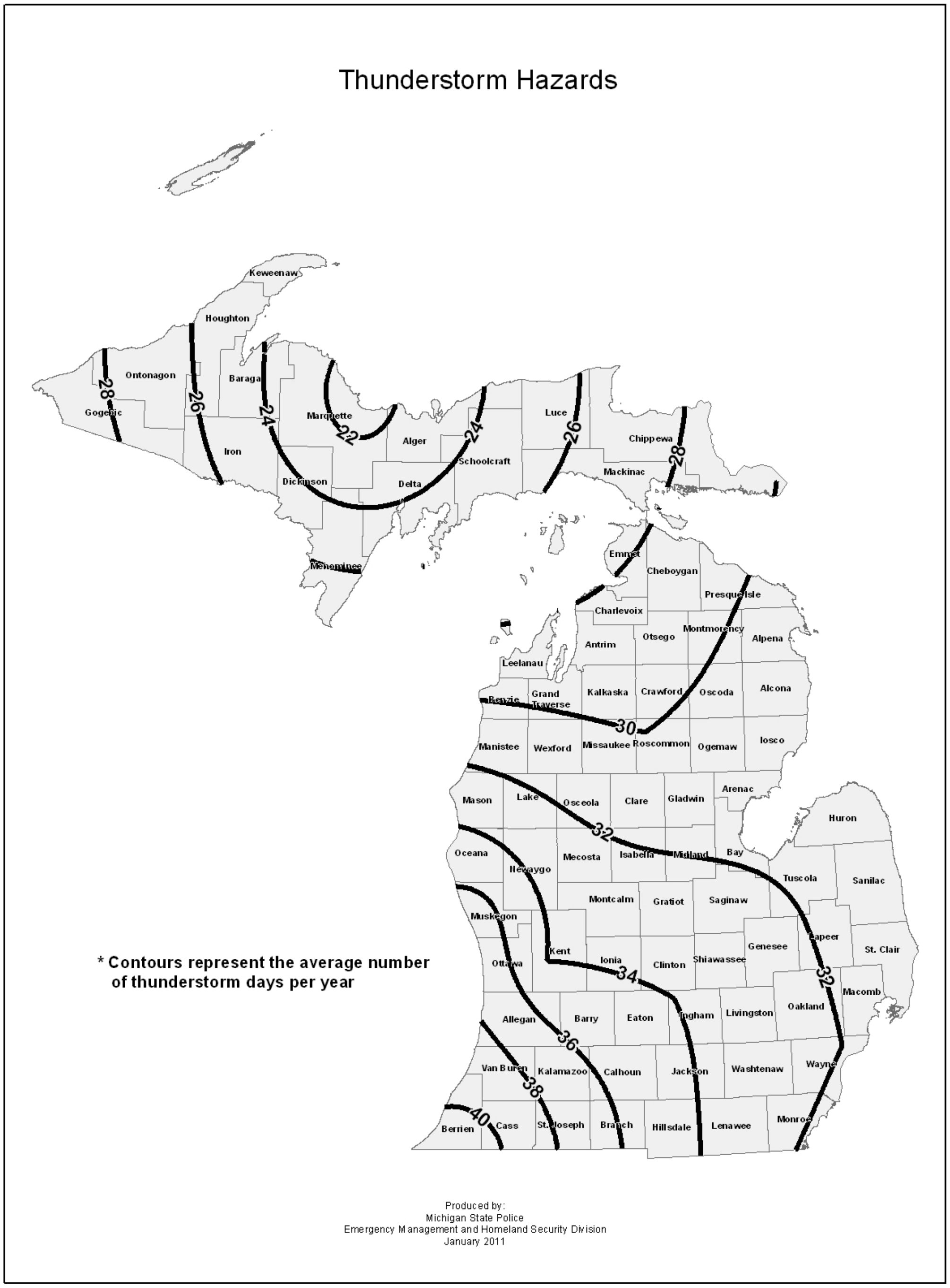
There is a strong connection between all of these extreme weather events and the "technological hazard" of infrastructure failure, which has its own chapter in the "Technological Hazards" section of this plan. Severe weather has also been a factor in major transportation accidents, which also has a chapter of its own in the Technological Hazards section.

Revised Treatment of Hazard Mitigation Strategies in this Edition of the MHMP

Previous MSP/EMHSD documents have tended to consider a wide array of activities that could in some manner help to protect lives, property, the environment, etc., without clearly distinguishing which of these activities are hazard mitigation and which ones deal with other phases of emergency management (preparedness, response, or recovery). This plan update will emphasize, where possible, the types of activities that are most properly considered to be hazard mitigation, especially those that are (or should be) eligible for federal funding. The reason for this change is because of a large number of local hazard mitigation plans that predominantly identify preparedness activities rather than hazard mitigation. It must be admitted that not all of the hazards faced by Michigan are ones that have very clear-cut hazard mitigation activities, although many preparedness, response, and recovery activities have already been identified in the previous edition of this plan. **Input is requested from all readers to help identify effective hazard mitigation activities for inclusion in this (as well as future and local-level) hazard mitigation document(s).**

Thunderstorm Hazards

Severe thunderstorms are weather systems accompanied by strong winds (at least 56mph), lightning, heavy rain (that could cause flash flooding), hail (at least ¾" diameter), or tornadoes. Severe thunderstorms can occur at any time in Michigan, although they are most frequent during the warm spring and summer months from May through September. The potential thunderstorm threat is often measured by the number of "thunderstorm days" – defined as days in which thunderstorms are observed. As the map below indicates, various areas in Michigan are subject to an average of at least 20 thunderstorm days per year, and up to just over 40 days per year in the state's southwestern corner. The Lower Peninsula, in general, is subject to approximately 28-40 thunderstorm days per year, while the Upper Peninsula average is closer to 20-30 thunderstorm days per year. This map is based upon new weather service data from various weather stations within (and near) Michigan.



Thunderstorms form when a shallow layer of warm, moist air is overrun by a deeper layer of cool, dry air. Cumulonimbus clouds, frequently called "thunderheads," are formed in these conditions. These clouds are often enormous (up to six miles or more across and 40,000 to 50,000 feet high) and may contain tremendous amounts of water and energy. That energy is often released in the form of high winds, excessive rains, lightning, and possibly hail and tornadoes.

Thunderstorms are typically short-lived (often lasting no more than 30-40 minutes) and fast moving (30-50 miles per hour). Strong frontal systems, however, may spawn one squall line after another, composed of many individual thunderstorm cells. Severe thunderstorms may also cause severe flood problems because of the torrential rains that they may bring to an area. Thunderstorms sometimes move very slowly, and can thus dump a tremendous amount of precipitation onto a location. Flooding can result, including flash floods, "urban flooding," and riverine flooding. Please refer to the hydrological hazard section for more information about these hazards. Large complexes of thunderstorms, called mesoscale convection systems (MCS), may operate as a larger-scale weather system and persist for several hours or more.

The following sections address in greater detail these specific thunderstorm hazards: 1) hail; 2) lightning; 3) severe winds; and 4) tornadoes (although most of these hazards can also occur when no thunderstorm activity is evident).

One positive aspect of assessing thunderstorm risks comes from the fact that thunderstorm hazards have some degree of predictability and are closely monitored by the National Weather Service. In addition to daily forecasts, which predict the probability of rainy or stormy weather, the NWS system of Watches and Warnings helps communities understand when there is a potential risk of severe thunderstorms, or if severe thunderstorms are imminent. When the NWS issues a "Severe Thunderstorm Watch," it means that thunderstorms with large hail and damaging winds are possible in your area. When the NWS issues a "Severe Thunderstorm Warning," it signifies that severe thunderstorms (with the damaging winds and hail) are in your area or are imminent.

The NWS has five offices that serve Michigan and are responsible for monitoring and providing predictions and bulletins for the entire state. The five offices are in Grand Rapids, Detroit, Gaylord, Marquette, and North Webster (Indiana). These stations provide information on severe weather watches and warnings, but also provide useful Doppler Radar images that track the movement of thunderstorms in your area. The North Webster office covers portions of southwest Michigan (www.weather.gov/iwx); the Grand Rapids station covers the remainder of southwest Michigan (www.weather.gov/grr); the Detroit station covers Southeast Michigan (www.weather.gov/dtx); the Gaylord station covers the north central portion of the Lower Peninsula and the eastern edge of the Upper Peninsula (www.weather.gov/apx); and the Marquette station examines the majority of the Upper Peninsula (www.weather.gov/mqt).

Since thunderstorms bring the potential for dangerous hail, lightning, straight-line winds, and tornadoes, it is necessary to further examine each of those hazards in the other sections of this plan. **Useful historical information on hail, severe winds, lightning, and tornadoes for your county can be found through the National Climatic Data Center's Storm Data website at** http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms. Data for each county in the state are listed there, and there are historical records of significant events for dozens of hazards. This is one of the most convenient information sources for the analysis of hazards, and was used extensively in this plan.

Hazard Mitigation Strategies for General Thunderstorm Hazards

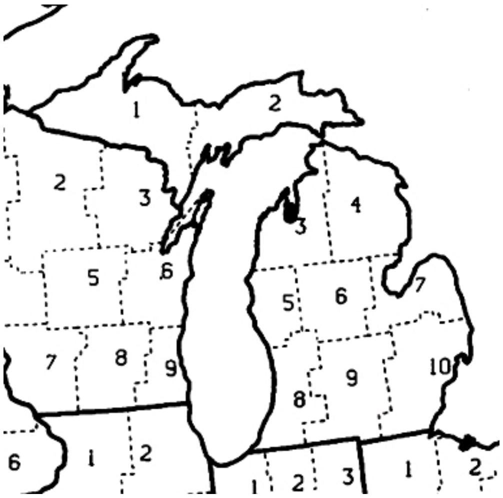
- Increased coverage and use of NOAA Weather Radio.
- Public early warning systems and networks.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines (where appropriate).

Emphasis in Local Hazard Mitigation Plans

Thunderstorms were identified as one of the most significant hazard in local hazard mitigation plans for the following counties: Allegan, Antrim, Arenac, Calhoun, Cass, Clare, Delta, Emmet, Genesee, Grand Traverse, Gratiot, Huron, Ionia, Isabella, Kalamazoo, Kalkaska, Leelanau, Luce, Mackinac, Marquette, Missaukee, Ogemaw, Osceola, Roscommon, Saginaw, Shiawassee, Tuscola, Washtenaw, and Wayne.

Michigan's 10 climate divisions (for the monitoring and analysis of precipitation)

Source: Rainfall Frequency Atlas of the Midwest, by Floyd A Huff and James R. Angel. Midwestern Climate Center and Illinois State Water Survey, 1992



Instructions for the Use of This Section

This section is useful for the assessment of rain and thunderstorm events, with implications also for flash flooding. It allows various levels of rainfall precipitation events to be interpreted in terms of their severity, based upon the historical frequency with which such events had occurred in the past.

The map at left shows Michigan's ten climate divisions, each of which is matched with data in the multi-page table below. (See page 136 for a list of counties located within each division.) The table contains sections listing numbers for each of Michigan's ten divisions. For a given precipitation event, find the row that most closely matches the duration of the rainfall event. Move across the row to find the number that is closest to the number of inches of rainfall for that event. The column in which that number appears tells the "recurrence interval" for that level of precipitation. A recurrence interval is the average amount of time that elapses between precipitation events of that particular severity level. Longer recurrence intervals indicate a more severe event. The most extreme events listed in the table are those with a 100-year recurrence interval. Such events are so severe that they are expected (on average) to occur only about one time per century. Precipitation-based flooding is more likely to result from events with a longer recurrence interval. Any Michigan rainfall amounts that exceed the values listed in the table are very rare and severe indeed!

As an example of the procedure described above, if an Ingham County event had caused 3 inches of rain to fall during a 6-hour period, the Division 9 section of the table contains a row labeled "6-hr" and the column that most closely matches the 3" rainfall amount contains a value of 3.07", matching up with a 25-year recurrence interval (definitely a major rainfall event).

Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
01	10-day	1.69	2.04	2.35	2.76	3.17	3.45	4.28	5.34	6.17	7.27	8.11	8.99
01	5-day	1.41	1.69	1.91	2.22	2.55	2.77	3.38	4.23	4.91	5.86	6.65	7.50
01	72-hr	1.24	1.46	1.65	1.91	2.20	2.39	2.96	3.69	4.29	5.11	5.79	6.49
01	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.64	3.31	3.84	4.59	5.20	5.86
01	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.39	3.00	3.48	4.17	4.73	5.32
01	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.25	2.82	3.27	3.92	4.45	5.00
01	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.08	2.61	3.03	3.63	4.12	4.63
01	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.79	2.25	2.61	3.13	3.55	3.99
01	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.53	1.92	2.23	2.67	3.03	3.40
01	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.39	1.74	2.02	2.42	2.74	3.09
01	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.12	1.41	1.64	1.96	2.22	2.50
01	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.29	1.54	1.75	1.97
01	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.65	0.81	0.94	1.13	1.28	1.44
01	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.73	0.88	0.99	1.12
01	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.29	0.36	0.42	0.50	0.57	0.64
02	10-day	1.61	1.94	2.23	2.62	3.02	3.28	3.93	4.78	5.44	6.43	7.22	7.98
02	5-day	1.25	1.50	1.70	1.97	2.26	2.46	3.00	3.71	4.25	5.11	5.81	6.55
02	72-hr	1.15	1.35	1.52	1.77	2.03	2.21	2.62	3.27	3.78	4.57	5.23	5.94
02	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.31	2.98	3.49	4.24	4.88	5.55
02	24-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.09	2.71	3.19	3.87	4.44	5.03
02	18-hr	0.86	1.00	1.09	1.26	1.44	1.56	1.96	2.55	3.00	3.64	4.17	4.73
02	12-hr	0.79	0.92	1.01	1.17	1.32	1.44	1.82	2.36	2.78	3.37	3.86	4.38
02	6-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.57	2.03	2.39	2.90	3.33	3.77
02	3-hr	0.58	0.68	0.74	0.86	0.98	1.06	1.34	1.73	2.04	2.48	2.84	3.22
02	2-hr	0.53	0.61	0.67	0.78	0.88	0.96	1.21	1.57	1.85	2.24	2.58	2.92
02	1-hr	0.43	0.50	0.55	0.63	0.72	0.78	0.98	1.27	1.50	1.82	2.09	2.36
02	30-min	0.34	0.39	0.43	0.49	0.56	0.61	0.77	1.00	1.18	1.43	1.64	1.86
02	15-min	0.25	0.29	0.31	0.36	0.41	0.45	0.56	0.73	0.86	1.04	1.20	1.36
02	10-min	0.19	0.22	0.24	0.28	0.32	0.35	0.44	0.57	0.67	0.81	0.93	1.06
02	5-min	0.11	0.13	0.14	0.16	0.18	0.20	0.25	0.33	0.38	0.46	0.53	0.60

Page 2 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for each given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
03	10-day	1.63	1.96	2.26	2.66	3.06	3.33	3.99	4.92	5.65	6.66	7.50	8.35
03	5-day	1.29	1.54	1.75	2.02	2.33	2.53	3.10	3.91	4.57	5.46	6.23	7.04
03	72-hr	1.09	1.27	1.44	1.67	1.92	2.09	2.62	3.36	3.96	4.86	5.56	6.35
03	48-hr	0.97	1.13	1.26	1.46	1.68	1.83	2.34	3.02	3.55	4.31	4.94	5.60
03	24-hr	0.89	1.04	1.13	1.31	1.49	1.62	2.09	2.70	3.21	3.89	4.47	5.08
03	18-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.96	2.54	3.02	3.66	4.20	4.78
03	12-hr	0.78	0.90	0.99	1.14	1.30	1.41	1.82	2.35	2.79	3.38	3.89	4.42
03	6-hr	0.67	0.78	0.85	0.99	1.12	1.22	1.57	2.03	2.41	2.92	3.35	3.81
03	3-hr	0.57	0.67	0.73	0.84	0.96	1.04	1.34	1.73	2.05	2.49	2.86	3.25
03	2-hr	0.52	0.60	0.66	0.76	0.86	0.94	1.21	1.57	1.86	2.26	2.59	2.95
03	1-hr	0.42	0.49	0.53	0.62	0.70	0.76	0.98	1.27	1.51	1.83	2.10	2.39
03	30-min	0.33	0.38	0.42	0.49	0.55	0.60	0.77	1.00	1.19	1.44	1.65	1.88
03	15-min	0.24	0.28	0.31	0.36	0.40	0.44	0.56	0.73	0.87	1.05	1.21	1.37
03	10-min	0.19	0.22	0.24	0.28	0.31	0.34	0.44	0.57	0.67	0.82	0.94	1.07
03	5-min	0.10	0.12	0.13	0.15	0.17	0.19	0.25	0.32	0.39	0.47	0.54	0.61
04	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.77	4.56	5.22	6.10	6.85	7.60
04	5-day	1.26	1.51	1.70	1.98	2.27	2.47	2.99	3.68	4.23	4.97	5.58	6.23
04	72-hr	1.12	1.31	1.48	1.72	1.98	2.15	2.63	3.27	3.75	4.45	5.00	5.60
04	48-hr	1.00	1.17	1.30	1.51	1.74	1.89	2.32	2.88	3.33	3.93	4.43	4.95
04	24-hr	0.94	1.09	1.20	1.39	1.57	1.71	2.11	2.62	3.04	3.60	4.06	4.53
04	18-hr	0.89	1.03	1.13	1.30	1.48	1.61	1.98	2.46	2.86	3.38	3.82	4.26
04	12-hr	0.82	0.95	1.04	1.21	1.37	1.49	1.84	2.28	2.64	3.13	3.53	3.94
04	6-hr	0.70	0.82	0.90	1.04	1.18	1.28	1.58	1.96	2.28	2.70	3.05	3.40
04	3-hr	0.60	0.70	0.76	0.88	1.00	1.09	1.35	1.68	1.95	2.30	2.60	2.90
04	2-hr	0.54	0.63	0.69	0.80	0.91	0.99	1.22	1.52	1.76	2.09	2.35	2.63
04	1-hr	0.44	0.51	0.56	0.65	0.74	0.80	0.99	1.23	1.43	1.69	1.91	2.13
04	30-min	0.35	0.40	0.44	0.51	0.58	0.63	0.78	0.97	1.12	1.33	1.50	1.68
04	15-min	0.25	0.29	0.32	0.37	0.42	0.46	0.57	0.71	0.82	0.97	1.10	1.22
04	10-min	0.20	0.23	0.25	0.29	0.33	0.36	0.44	0.55	0.64	0.76	0.85	0.95
04	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.25	0.31	0.36	0.43	0.49	0.54
05	10-day	1.64	1.97	2.27	2.67	3.07	3.34	4.14	5.28	6.21	7.59	8.75	10.02
05	5-day	1.38	1.65	1.86	2.16	2.48	2.70	3.36	4.30	5.07	6.25	7.26	8.36
05	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.88	3.74	4.46	5.45	6.31	7.26
05	48-hr	1.04	1.22	1.36	1.58	1.81	1.97	2.53	3.34	4.01	4.97	5.81	6.73
05	24-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.28	3.00	3.60	4.48	5.24	6.07
05	18-hr	0.91	1.06	1.16	1.34	1.53	1.66	2.14	2.82	3.38	4.21	4.93	5.71
05	12-hr	0.85	0.99	1.08	1.25	1.42	1.54	1.98	2.61	3.13	3.90	4.56	5.28
05	6-hr	0.73	0.85	0.93	1.08	1.22	1.33	1.71	2.25	2.70	3.36	3.93	4.55
05	3-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.46	1.92	2.30	2.87	3.35	3.88
05	2-hr	0.57	0.66	0.72	0.83	0.95	1.03	1.32	1.74	2.09	2.60	3.04	3.52
05	1-hr	0.46	0.53	0.58	0.67	0.76	0.83	1.07	1.41	1.69	2.11	2.46	2.85
05	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.84	1.11	1.33	1.66	1.94	2.25
05	15-min	0.26	0.31	0.34	0.39	0.44	0.48	0.62	0.81	0.97	1.21	1.41	1.64
05	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.48	0.63	0.76	0.94	1.10	1.27
05	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.27	0.36	0.43	0.54	0.63	0.73
06	10-day	1.76	2.12	2.44	2.87	3.30	3.59	4.31	5.36	6.21	7.46	8.51	9.54
06	5-day	1.44	1.72	1.95	2.26	2.59	2.82	3.40	4.22	4.89	6.11	7.17	8.31
06	72-hr	1.23	1.45	1.64	1.90	2.18	2.37	2.88	3.62	4.24	5.27	6.17	7.18
06	48-hr	1.09	1.28	1.42	1.65	1.90	2.06	2.51	3.17	3.71	4.59	5.35	6.20
06	24-hr	1.02	1.19	1.30	1.51	1.71	1.86	2.27	2.85	3.34	4.15	4.84	5.62
06	18-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.13	2.68	3.14	3.90	4.55	5.28
06	12-hr	0.89	1.04	1.13	1.31	1.49	1.62	1.97	2.48	2.91	3.61	4.21	4.89
06	6-hr	0.76	0.89	0.97	1.13	1.28	1.39	1.70	2.14	2.50	3.11	3.63	4.22
06	3-hr	0.65	0.76	0.83	0.96	1.09	1.19	1.45	1.82	2.14	2.66	3.10	3.60
06	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.32	1.65	1.94	2.41	2.81	3.26
06	1-hr	0.48	0.56	0.61	0.70	0.80	0.87	1.07	1.34	1.57	1.95	2.27	2.64
06	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.05	1.24	1.54	1.79	2.08
06	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.77	0.90	1.12	1.31	1.52
06	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.48	0.60	0.70	0.87	1.02	1.18
06	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.34	0.40	0.50	0.58	0.67

Page 3 of Table: Mean Frequency Distributions for Storm Periods of 5 Minutes to 10 Days, by Climate Division, and Recurrence Intervals of 2 Months to 100 Years in Michigan (for use with thunderstorm and flood hazards)

		Rainfall (inches) for given recurrence interval											
Division	*Duration*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
07	10-day	1.57	1.89	2.18	2.56	2.94	3.20	3.88	4.75	5.39	6.21	6.83	7.48
07	5-day	1.22	1.46	1.66	1.92	2.21	2.40	2.96	3.68	4.23	4.99	5.61	6.26
07	72-hr	1.11	1.30	1.47	1.70	1.96	2.13	2.62	3.28	3.78	4.49	5.05	5.66
07	48-hr	1.02	1.20	1.33	1.54	1.78	1.93	2.37	2.97	3.41	4.03	4.52	5.04
07	24-hr	0.96	1.12	1.23	1.42	1.61	1.75	2.14	2.65	3.05	3.56	3.97	4.40
07	18-hr	0.90	1.05	1.15	1.33	1.51	1.64	2.01	2.49	2.87	3.35	3.73	4.14
07	12-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.86	2.31	2.65	3.10	3.45	3.83
07	6-hr	0.72	0.84	0.92	1.06	1.21	1.31	1.61	1.99	2.29	2.67	2.98	3.30
07	3-hr	0.62	0.72	0.78	0.91	1.03	1.12	1.37	1.70	1.95	2.28	2.54	2.82
07	2-hr	0.56	0.65	0.71	0.82	0.93	1.01	1.24	1.54	1.77	2.06	2.30	2.55
07	1-hr	0.45	0.52	0.57	0.66	0.75	0.82	1.01	1.25	1.43	1.67	1.87	2.07
07	30-min	0.36	0.42	0.45	0.53	0.60	0.65	0.79	0.98	1.13	1.32	1.47	1.63
07	15-min	0.26	0.30	0.33	0.38	0.43	0.47	0.58	0.72	0.82	0.96	1.07	1.19
07	10-min	0.20	0.24	0.26	0.30	0.34	0.37	0.45	0.56	0.64	0.75	0.83	0.92
07	5-min	0.12	0.13	0.15	0.17	0.19	0.21	0.26	0.32	0.37	0.43	0.48	0.53
08	10-day	1.81	2.18	2.51	2.95	3.39	3.69	4.33	5.23	5.96	7.39	8.63	10.03
08	5-day	1.48	1.77	2.00	2.32	2.67	2.90	3.45	4.27	4.95	6.16	7.28	8.46
08	72-hr	1.29	1.52	1.72	1.99	2.29	2.49	3.00	3.75	4.41	5.50	6.45	7.51
08	48-hr	1.14	1.33	1.48	1.72	1.98	2.15	2.63	3.32	3.91	4.93	5.83	6.82
08	24-hr	1.07	1.25	1.37	1.58	1.79	1.95	2.37	3.00	3.52	4.45	5.27	6.15
08	18-hr	1.01	1.17	1.28	1.48	1.68	1.83	2.23	2.82	3.31	4.18	4.95	5.78
08	12-hr	0.94	1.09	1.19	1.38	1.56	1.70	2.06	2.61	3.06	3.87	4.58	5.35
08	6-hr	0.80	0.93	1.02	1.18	1.34	1.46	1.78	2.25	2.64	3.34	3.95	4.61
08	3-hr	0.69	0.80	0.88	1.01	1.15	1.25	1.52	1.92	2.25	2.85	3.37	3.94
08	2-hr	0.62	0.72	0.79	0.92	1.04	1.13	1.37	1.74	2.04	2.58	3.06	3.57
08	1-hr	0.51	0.59	0.64	0.75	0.85	0.92	1.11	1.41	1.65	2.09	2.48	2.89
08	30-min	0.40	0.46	0.50	0.58	0.66	0.72	0.88	1.11	1.30	1.65	1.95	2.28
08	15-min	0.29	0.34	0.37	0.43	0.49	0.53	0.64	0.81	0.95	1.20	1.42	1.66
08	10-min	0.23	0.26	0.29	0.33	0.38	0.41	0.50	0.63	0.74	0.93	1.11	1.29
08	5-min	0.13	0.15	0.16	0.19	0.21	0.23	0.28	0.36	0.42	0.53	0.63	0.74
09	10-day	1.77	2.13	2.45	2.89	3.32	3.61	4.26	5.15	5.83	6.81	7.60	8.40
09	5-day	1.43	1.71	1.93	2.24	2.58	2.80	3.36	4.10	4.71	5.57	6.27	6.99
09	72-hr	1.27	1.49	1.68	1.95	2.24	2.44	2.93	3.59	4.16	4.95	5.59	6.28
09	48-hr	1.17	1.37	1.52	1.77	2.03	2.21	2.66	3.28	3.79	4.50	5.10	5.73
09	24-hr	1.12	1.30	1.42	1.64	1.87	2.03	2.42	2.98	3.43	4.09	4.63	5.20
09	18-hr	1.05	1.22	1.34	1.55	1.76	1.91	2.27	2.80	3.22	3.84	4.35	4.89
09	12-hr	0.97	1.13	1.24	1.43	1.63	1.77	2.11	2.59	2.98	3.56	4.03	4.52
09	6-hr	0.84	0.97	1.06	1.23	1.40	1.52	1.82	2.24	2.57	3.07	3.47	3.90
09	3-hr	0.71	0.83	0.91	1.05	1.20	1.30	1.55	1.91	2.20	2.62	2.96	3.33
09	2-hr	0.65	0.76	0.83	0.96	1.09	1.18	1.40	1.73	1.99	2.37	2.69	3.02
09	1-hr	0.52	0.61	0.66	0.77	0.87	0.95	1.14	1.40	1.61	1.92	2.18	2.44
09	30-min	0.41	0.48	0.52	0.61	0.69	0.75	0.90	1.10	1.27	1.51	1.71	1.92
09	15-min	0.30	0.35	0.38	0.45	0.51	0.55	0.65	0.80	0.93	1.10	1.25	1.40
09	10-min	0.24	0.28	0.30	0.35	0.40	0.43	0.51	0.63	0.72	0.86	0.97	1.09
09	5-min	0.13	0.15	0.17	0.19	0.22	0.24	0.29	0.36	0.41	0.49	0.56	0.62
10	10-day	1.56	1.88	2.17	2.55	2.93	3.19	3.82	4.64	5.27	6.11	6.79	7.51
10	5-day	1.28	1.53	1.73	2.01	2.31	2.51	3.05	3.68	4.16	4.78	5.26	5.74
10	72-hr	1.18	1.38	1.56	1.81	2.08	2.26	2.74	3.34	3.76	4.31	4.74	5.16
10	48-hr	1.08	1.26	1.41	1.63	1.88	2.04	2.48	3.04	3.44	3.96	4.36	4.78
10	24-hr	1.03	1.20	1.31	1.51	1.72	1.87	2.26	2.75	3.13	3.60	3.98	4.36
10	18-hr	0.97	1.13	1.23	1.43	1.62	1.76	2.12	2.59	2.94	3.38	3.74	4.10
10	12-hr	0.90	1.04	1.14	1.32	1.50	1.63	1.97	2.39	2.72	3.13	3.46	3.79
10	6-hr	0.77	0.90	0.98	1.13	1.29	1.40	1.69	2.06	2.35	2.70	2.99	3.27
10	3-hr	0.66	0.77	0.84	0.97	1.10	1.20	1.45	1.76	2.00	2.30	2.55	2.79
10	2-hr	0.59	0.69	0.76	0.87	0.99	1.08	1.31	1.59	1.82	2.09	2.31	2.53
10	1-hr	0.48	0.56	0.62	0.71	0.81	0.88	1.06	1.29	1.47	1.69	1.87	2.05
10	30-min	0.38	0.44	0.48	0.56	0.63	0.69	0.84	1.02	1.16	1.33	1.47	1.61
10	15-min	0.28	0.32	0.35	0.41	0.46	0.50	0.61	0.74	0.85	0.97	1.07	1.18
10	10-min	0.21	0.25	0.27	0.32	0.36	0.39	0.47	0.58	0.66	0.76	0.84	0.92
10	5-min	0.12	0.14	0.15	0.18	0.20	0.22	0.27	0.33	0.38	0.43	0.48	0.52

Hail

Conditions where atmospheric water particles from thunderstorms form into rounded or irregular lumps of ice that fall to the earth.

Hazard Description

Hail is produced by thunderstorms when strong updrafts among the clouds carry water droplets above the freezing level and cause the formation of ice pellets around some nucleus (such as a water crystal or speck of dust). These can remain suspended in the winds and can continue to grow larger until their weight is no longer supportable and they fall to earth, possibly accompanied by heavy rains. Falling hailstones batter crops, dent autos, and injure wildlife and people. Large hail is a characteristic of severe thunderstorms, and it may precede the occurrence of a tornado.

Hail can be especially damaging to crops, home roofs, and automobiles. Approximately $1 billion in damages occurs annually across the United States. In Michigan, there is usually at least one intense hailstorm per year that causes significant damages. Unfortunately, for many hailstorms, the total damages to property go unreported.

As a product of the strong thunderstorms that frequently move across the state, the size of hail is usually proportional to the intensity of the storm cell that generates it. As a thunderstorm passes over, hail usually falls near the center of the storm, along with the heaviest rain. Sometimes, strong winds occurring at high altitudes in the thunderstorm can blow the hailstones away from the storm center, causing an unexpected hazard at places that otherwise might not appear threatened.

Hazard Analysis

Most hailstones reported in Michigan range in size from a pea (¼” diameter) to a golf ball (1¾” diameter), but hailstones larger than baseballs (2¾” diameter) have occurred with the most severe thunderstorms. In 2009, the official cut-point that denotes severe hail events was increased from 0.75” to 1.00”. The following table provides the official classifications of hail magnitude, as often used in weather reporting and event records. Some statistics cover multiple categories of hail magnitude (by combining table cells together).

Descriptive size of hail	Diameter	Number of MI events (1996-2013)	Impacts:	Areas of occurrence
Pea	¼” (6mm)	Too many to include	Common occurrence. Impacts not tallied—usually minimal.	Every county in Michigan
Marble or mothball	½” (13mm)			
Penny or dime	¾” (19mm)	} 2080	Old threshold for severe hail, raised to 1” in 2009.	Every county in Michigan
Nickel	0.9” (22mm)	}		
Quarter	1” (25mm)	} 1022	$70,028,000 property damage, $2.79M in crop damage	Every county in Michigan
Half-dollar	1¼” (32mm)	}		
Walnut or ping-pong ball	1½” (38mm)	} 427	$201.229M property damage, $3.025M crop damage, 3 inj.	Almost all counties across the state
Golf ball	1¾” (44mm)	}		
Hen’s egg	2” (51mm)	52	$7.33 million in property damage, $615,000 in crop damages, 1 injury	43 counties located across the entire state
Tennis ball	2½” (64mm)	8		
Baseball	2¾” (70mm)	14		
Tea cup	3” (76mm)	7	$6.031M in property damage	Worst in Western U.P.
Grapefruit	4” (102mm)	2	$800K in property damage	Gogebic, Jackson
Softball	4½” (114mm)	0		
	TOTAL:	3612	$288M property, $8M crop	All MI counties

Sources: Two left columns—Coenraads 2006:224, three right columns—NCDC Storm Events database.

The likelihood of severe hailstorms in specific Michigan counties is expected to be proportional to the frequency of thunderstorms in that county, but as the tables in this chapter show, the impacts of hail are much harder to characterize than the mere frequency of occurrence (of which the map of Michigan thunderstorm days in the preceding section might provide a general indication).

Hail History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Hail Events	Days with Hail	Tot. property damage	Tot. crop damage	Injuries
Washtenaw	154	65	$10,000		
Wayne	146	63	$7,000		
.Livingston	45	27			
Oakland	147	67	$11,000		
Macomb	122	62	$2,000		
5 Co Metro region	123 avg.	57 avg.	Total $30,000	-	0
Berrien	39	24	$8,000	$1,300,000	
Cass	23	19	$12,000		
St. Joseph	41	25			
Branch	54	29	$1,000,000		
Hillsdale	35	23	$2,000,000		
Lenawee	91	49	$2,150,000		1
Monroe	74	42			
.Van Buren	26	22	$50,355,000	$230,000	
Kalamazoo	54	40	$129,680,000	$370,000	
Calhoun	34	14	$325,000	$285,000	
Jackson	37	33	$380,000	$225,000	
.Allegan	47	30	$652,000	$372,000	
Barry	39	32	$360,000	$205,000	
Eaton	41	33	$435,000	$325,000	
Ingham	40	26	$400,000	$235,000	
.Ottawa	53	39	$497,000	$297,000	
Kent	74	50	$14,952,000	$370,000	
Ionia	14	13	$4,175,000	$100,000	
Clinton	26	19	$150,000	$115,000	
Shiawassee	36	28	$2,800,000	$2,000,000	
Genesee	157	64			
Lapeer	59	34			
St. Clair	71	37	$125,000		
.Muskegon	40	26	$425,000	$250,000	
Montcalm	25	20	$1,145,000	$135,000	1
Gratiot	25	19	$145,000	$120,000	
Saginaw	86	38	$300		
Tuscola	65	44			
Sanilac	49	33	$155,000	$10,000	
.Mecosta	22	18	$315,000	$160,000	
Isabella	33	21	$145,000	$170,000	
Midland	72	38	$1,000		
Bay	41	27			2
Huron	54	37	$5,000		
34 Co S Lower Pen	49 avg.	31 avg.	Total $212,792,300	Total $7,274,000	4

Continued on next page…

Part 2 of Hail History for Michigan Counties – arranged by region

.Oceana	21	18	$200,000	$115,000	
Newaygo	28	21	$245,000	$150,000	
.Mason	16	12	$80,000	$25,000	
Lake	15	12	$110,000	$65,000	
Osceola	14	12	$75,000	$70,000	
Clare	29	25	$455,000	$110,000	
Gladwin	29	24			
Arenac	31	22			
.Manistee	19	12		$35,000	
Wexford	22	18			
Missaukee	14	13			
Roscommon	31	25			
Ogemaw	35	20			
Iosco	47	28			
.Benzie	9	8			
Grand Traverse	18	15			
Kalkaska	9	9			
Crawford	18	15			
Oscoda	34	20			
Alcona	41	28			
.Leelanau	29	19		$55,000	
Antrim	25	16		$30,000	
Otsego	36	18			
Montmorency	25	20			
Alpena	28	19			
.Charlevoix	26	19			
Emmet	15	12	$100,000		
Cheboygan	15	12			
Presque Isle	26	18	$3,500,000	$300,000	1
29 Co N Lower Pen	24 avg.	18 avg.	Total $4,765,000	Total $955,000	1
Gogebic	45	25	$750,000		
Iron	42	26	$4,100,000		
Ontonagon	45	31			
Houghton	43	24	$10,000		
Keweenaw	4	4			
Baraga	31	24			
.Marquette	114	50	$64,647,000		
Dickinson	54	35	$225,000		
Menominee	54	34	$100,000		
Delta	63	33	$4,000		
Schoolcraft	32	25	$100,000		
Alger	40	24	$5,000		
.Luce	15	14			
Mackinac	12	10			
Chippewa	22	15			
15 Co Upper Pen	41 avg.	25 avg.	Total $69,941,000	-	0
MICHIGAN TOTAL	3,612	584	$287,523,300	$8,229,000	5

Although damaging hail is much less frequent than thunderstorms, since only a fraction of all thunderstorms produce damaging hail, there is still an unusual aspect to the types of events that cause damages to occur. Hail is most likely for severe thunderstorms that also produce great amounts of precipitation, but although damaging hail has occurred in every part of Michigan, the events producing the largest-sized hail are not always reported to be damaging, and much smaller-sized hail often causes far greater negative impacts. The vast majority of reported property damage in Michigan stems from just a few events. This unusual pattern is also reflected in the geographic variation in damage reports by county. As shown in the 2-page table on the previous pages, most of the property damage caused by hail in the past 18 years had been reported within just a few counties: Kalamazoo, Marquette, and Van Buren. The pattern seen in the data suggests a geographic component to damaging hail risks—since there is no clear reason why the Detroit Metro area would be more damage-resistant than the Kalamazoo or Grand Rapids areas, the severe hail damages in the latter areas would appear to either stem from pure chance or from geographic differences across Michigan. This geographic hypothesis suggests that there are two areas of strongest risk from damaging hail: those in the inland-southwestern areas of the Lower Peninsula, and the Iron-Marquette portion of the Central Upper Peninsula.

Alternatively, the geographic pattern of the worst recent hail events may just be an artifact of the relatively small number of severely damaging events. If so, then the severe hail hazard might be characterized in a manner similar to tornadoes, in that a severe event has the potential to cause severe damage to any location in Michigan, but that the chance of any specific location being struck is very rare. Therefore, for most of Michigan's citizens, hail will appear to be a mere curiosity that seems infrequent and harmless. This impression is held by far fewer persons who are responsible for agricultural produce. They are aware that hail can be extremely harmful to their crops. Many kinds of produce are vulnerable to damage, whether fruit or vegetable: potatoes, beans, tomatoes, corn, soybeans, apples, peaches, grapes, plums, cherries and raspberries have all been severely damaged by hailstorms in Michigan.

Property damage often involves hail impacts upon motor vehicles, but widespread damage to the roofs and siding of homes can also occur. Even though automobiles can be protected in garages, some hail is large enough to cause damage to built structures themselves. Thus, in addition to the other types of thunderstorm hazards (lightning, winds and tornadoes, and excessive precipitation), serious damage can come from severe hail.

A major damaging hail event can be expected in Michigan at least once every 2 to 3 years, although the typical county will see such impacts only over the course of several decades. The National Weather Service began recording hail activity in Michigan in 1967. Statistics since that time indicate that approximately 50% of the severe thunderstorms that produce hail have occurred during the months of June and July, and nearly 80% have occurred during the prime growing season of May through August. As a result, the damage to crops from hail can be extensive.

There have been 5 injuries in Michigan due to hail events since the beginning of 1996. These involved persons who were outdoors and directly exposed to the impact of hailstones. Two of the injuries occurred in a sailboat during a hailstorm in 1999. Another was a motorcyclist who received a minor injury when struck on the mouth. The other injury documented on NCDC involved a person who was attempting to move a vehicle into a shelter, and was thus exposed.

The National Weather Service forecasts of severe thunderstorms usually give sufficient warning time to allow residents to take appropriate action to reduce the effects of hail damage on vehicles and some property. However, it is very difficult to prevent damage to crops. More details about specific Michigan events, and resulting damages, is provided in the subsection, below, about significant Michigan hailstorms. At least $100 million in property and crop damage has occurred from hail events in Michigan since 1990.

Impact on the Public

Hail generally causes minor property damage within its area of impact, but large hail also discourages the public from outdoor activities and events, due to concerns involving safety and comfort.

Impact on Public Confidence in State Governance

If hail causes infrastructure failures, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from the impacts of hail. Fortunately, most episodes of hail are brief and it is usually easy to take cover to avoid being injured.

Impact on the Environment

Hail is a product of strong thunderstorms, usually occurs along with the heaviest rain, and ranges in size from a pea to a golf ball (and in some rare occurrences, a baseball). The primary effects on the natural environment include physical damage to vegetation such as forests, plants, and crops, and physical harm to wildlife species. Plants with well-established root systems will seldom die, but some younger or smaller forms of vegetation may not survive a severe hail storm. Hail can damage some fruit and vegetable plants and render them unsuitable for consumption by humans. This can also lead to an increased risk of bacteria that can kill healthy trees as well as nearby wildlife. The impact of hail can cause soil erosion that can exacerbate flooding, and large ice can potentially clog or reduce the effectiveness of drainage paths, culverts, and grates.

Significant Hailstorms in Michigan since 1985

May 1985 - Lower Peninsula (western and eastern counties)

In May 1985, severe thunderstorms accompanied by hail struck the western and eastern counties of the Lower Peninsula, causing great damage. Two-inch hail was reported in Cass County and $2 million in damages to fruit crops were reported in Kent County.

March 27, 1991 - Lower Peninsula (central and southern counties)

On March 27, 1991 severe thunderstorms and accompanying high winds and hail caused considerable damage across a large portion of central and southern Lower Michigan, damaging homes, businesses, farms and some public facilities. A total of three deaths and 27 injuries were attributed to the storms. Egg to baseball-sized hail, some exceeding 2.5" in diameter, was reported in the vicinity of Buchanan in Berrien County. In Kalamazoo and Portage in Kalamazoo County, softball size hail, up to 4.5" in diameter, did extensive damage to automobiles, windows and trees.

April 12, 1996 - Lower Peninsula (southern counties)

Up to golf ball sized hail fell across southern Michigan along the path of severe thunderstorms. Tree limbs, power lines, windows, aluminum and vinyl siding on houses were damaged. Numerous recreational vehicles parked at a dealership were badly damaged. The event resulted in $6 million in property damage throughout southern Michigan.

July 2, 1997 - Lower Peninsula (Berrien County)

A severe thunderstorm during the early morning hours of July 2, 1997 pounded Berrien County with 1" to 2.25" diameter hail that caused agricultural losses of nearly $1 million. The hail destroyed 280 acres of fruits and 100 acres of vegetables in a two-mile wide swath from Stevensville southeast to the county line. Damaging hail was reported in numerous other locations across the Lower Peninsula on July 2 – just one of the impacts of a storm system that would eventually spawn deadly tornadoes in southeast Michigan and lead to a Presidential Disaster Declaration. (Refer to the Tornadoes section for additional information.)

June 24, 1998 - Lower Peninsula (central and southern counties)

On June 24, 1998 two tracts of severe thunderstorms crossed the state moving east to west – one tract stretched across central Lower Michigan, while the other moved into the southern portion of the state. The more northerly thunderstorms produced large amounts of hail in several counties, ranging from dime to quarter sized hail up to baseball size (2.75" in diameter) hail. Damage was widespread, but not overly severe. However, in Petoskey, hail (2.5" in diameter) caused $100,000 in damage to cars on two lots west of town. In Ingham County, near Onondaga, baseball-sized hail damaged auto glass and roofs, but specific damage figures were not available.

Sept. 26, 1998 - Lower Peninsula (northern counties)

A line of severe thunderstorms that ravaged northern Lower Michigan during the weekend of September 26-27, 1998 produced hail up to 2" in diameter in Manistee County, destroying an estimated 30,000-35,000 bushels of apples at area farms. The same storm system produced tennis ball-sized hail north of the town of Gladwin, which damaged several homes and vehicles. In Arenac County, near Sterling, 3.5" diameter hail damaged crops and injured some livestock at area farms, and damaged several homes, satellite dishes, and vehicles.

June 9, 2000 - Iron River (Iron County); Randville-Grand Bluff (Dickinson County)

In the early morning hours of June 9, 2000 a line of thunderstorms moved through Iron County, producing 1.75" hail that damaged approximately 575 homes and 700 vehicles in a two-mile wide swath across the northern two-thirds of the city of Iron River. The hail caused approximately $2.3 million in roof and siding damage. Ping-pong ball sized hail in the Randville-Grand Bluff area in Dickinson County caused $225,000 in damage to 20 homes and 20 vehicles. Total hail damage in Iron and Dickinson Counties was $4.1 million.

July 14, 2000 - Algonac (St. Clair County)

On the afternoon of July 14, 2000 severe thunderstorms producing large hail struck St. Clair County. Hailstones as large as baseballs (2.75" in diameter) fell in Algonac, causing $125,000 in damage to cars and homes. The hailstones damaged roofs, ripped gutters off of homes, dented air conditioning units, and broke windows. The force of impact when the hailstones landed in the canals in Algonac caused the water to splash five feet into the air.

July 13, 2004 - Posen (Presque Isle County)

On July 13, 2004 a devastating hailstorm caused extensive damage in the small town of Posen in Presque Isle County. The hail (2.75" in diameter) was driven at times by wind gusts around 60 miles per hour. Most buildings and vehicles in the community suffered some sort of damage. Holes were punched in roofs and siding, cars were dented and windows were broken. A local church had to patch 300 holes in its roof. Damage to a school roof was estimated at nearly $200,000, and a local greenhouse lost over a thousand two-foot by two-foot window panes. One individual suffered a badly bruised back as he tried to move his vehicle to shelter. Substantial damage was done to crops (largely potatoes, along with some beans, tomatoes and corn) in nearby fields.

July 28, 2006 – Western Upper Peninsula (Gogebic County)

An approaching cold front interacting with an extremely unstable airmass triggered a widespread outbreak of severe weather across western and central Upper Michigan from the late afternoon on the 28th until just after sunrise on the 29th. Hail of up to 4 inches in diameter resulted in significant damage to roofs, siding, and automobiles. Damage estimates in Wakefield and surrounding areas had been reported as over $60 million, but hail damages are currently listed in the NCDC storm events database as specifically totaling $750,000 in Wakefield. 11 counties across the Central and Western Upper Peninsula were also affected.

June 20, 2007 – Marquette (Marquette County)

One of the most significant hailstorms in memory pummeled downtown Marquette and Harvey during the afternoon of June 20, 2007. While most of the hail was less than golf ball size, there were a few reports of hail that was three inches in diameter. The hail accumulated to several inches deep in downtown Marquette, and storm drains clogged from shredded leaves caused melting hail to result in street flooding. Hundreds of houses sustained significant damage to roofs and sidings. In addition, thousands of cars were damaged. Damage estimates from the storm for Marquette and surrounding areas were reported to total over $60 million.

July 26, 2007 – Southern Lower Peninsula (especially Shiawassee, Muskegon, Lenawee Counties)

Large hail hammered areas in a 3 mile radius around Durand for 50 minutes. The hail, at times, was as big as golf balls. A local newspaper reported $1.8 million in hail damages to homes alone. Hundreds of homes and vehicles were significantly damaged, with the latter averaging $4,000 per vehicle. This resulted in an estimate of $1 million in total vehicle damages. Many crops in the area were also destroyed. One farmer estimated $400,000 in losses to soybeans alone. Total crop damages were conservatively estimated at $2 million, bringing the total cost of the hailstorm to nearly $5 million. A local newspaper reported $75,000 in total damages to patrol cars and other vehicles at the Lenawee County Fair. This event will be remembered for the extreme intensity of large hail that it generated.

April 5, 2010 – Southwestern Michigan

Severe thunderstorms produced large hail and winds greater than 80 mph. The most significant damage occurred in the southern portions of Kalamazoo County, with damages estimated at $125 million, but Van Buren County was also struck heavily, with damages estimated at $50 million. To the west-southwest of Schoolcraft (Kalamazoo County), the siding of many homes was destroyed on the homes' western sides, where it was battered by large hail of about 1.75 inches in diameter. The estimated damages from this storm event include strong wind effects, not just hail impacts.

April 26, 2011 – Southern Lower Peninsula (especially Kent, Ionia, and Kalamazoo Counties)

Several thunderstorm supercells produced large hail reported as up to 2" in diameter. An EF-0 tornado near Burnips (Allegan County) and an injurious lightning strike in Portage (Kalamazoo County) also occurred during this weather event. Hail damages included areas northeast of Belding (Ionia County, $4 million), south of Stanton (Montcalm County, $1 million), across northern Kalamazoo County ($4 million), and in Kent County ($2 million).

Programs and Initiatives

Note: Many of the programs and initiatives in place to mitigate, prepare for, respond to, and recover from other severe thunderstorms hazards (straight-line winds, lightning and tornadoes) have the dual purpose of also protecting against hail. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including storms that are likely to produce damaging hail. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

Doppler technology calculates both the speed and the direction of wind motion inside of severe storms. By providing data on the wind patterns within developing storms, the system allows forecasters to better identify the conditions leading to severe weather such as tornadoes, severe straight-line winds, lightning and damaging hail. This means early detection of the precursors to severe storms, as well as information on the direction and speed of storms once they form.

National Weather Service Watches/Warnings

The National Weather Service issues severe thunderstorm watches for areas when the meteorological conditions are conducive to the development of severe thunderstorms. People in the watch area are instructed to stay tuned to National Oceanic and Atmospheric Administration (NOAA) weather radio and local radio or television stations for weather updates, and watch for developing storms. Once radar or a trained Skywarn spotter detects the existence of a severe thunderstorm, the National Weather Service will issue a severe thunderstorm warning. The warning will identify where the storm is located, the direction in which it is moving, and the time frame during which the storm is expected to be in the area. Persons in the warning area are instructed to seek shelter immediately.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), NOAA weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet at www.weather.gov, where an interactive map can be used.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division of the Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week.

This annual public information and education campaign focuses on such severe weather events as tornadoes, thunderstorms, lightning, high winds, flooding and hail. Informational materials on hail and other thunderstorm hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Hazard Mitigation Activities for Hail

- Increased coverage and use of NOAA Weather Radio.
- Public early warning systems and networks.
- Tree trimming and maintenance to prevent limb breakage and to safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)
- Moving vehicles into garages or other covered areas.
- Inclusion of safety strategies for severe weather events in driver education classes and materials.
- Purchase of insurance that includes coverage for hail damage.
- Using structural bracing, window shutters, laminated glass in window panes, and impact-resistant roof shingles to minimize damage to public and private structures.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of hail), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the hail hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes hail information as it has been reported in local hazard mitigation plans. For a brief summary of hail-related information from that section of this plan, it will here be noted that hail was identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Antrim, Arenac, Clare, Genesee, Gratiot, Huron, Lapeer, Mackinac, Monroe, Ogemaw, Roscommon, Shiawassee, Washtenaw (13 counties, total).

Lightning

The discharge of electricity from within a thunderstorm.

Hazard Description

Lightning is a random and unpredictable product of a thunderstorm's tremendous energy. The energy in the storm produces an intense electrical field like a giant battery, with the positive charge concentrated at one end and the opposite charge concentrated at the other. Lightning strikes when a thunderstorm's electrical potential (the difference between its positive and negative charges) becomes great enough to overcome the resistance of the surrounding air. Bridging that difference, lightning can jump from cloud to cloud, cloud to ground, ground to cloud, or even from the cloud to the air surrounding the thunderstorm. Lightning strikes can generate current levels of 30,000 to 40,000 amperes, with air temperatures often superheated to higher than 50,000 degrees Fahrenheit (hotter than the surface of the sun) and speeds approaching one-third the speed of light.

Hazard Analysis

Globally, there are about 2,000 thunderstorms occurring at any given time, and those thunderstorms cause approximately 100 lightning strikes upon the ground each second. In the United States, approximately 100,000 thunderstorms occur each year, and every one of those storms generates lightning. It is not uncommon for a single thunderstorm to produce hundreds or even thousands of lightning strikes. However, to the majority of the general public, lightning is perceived as a minor hazard. That perception lingers despite the fact that lightning damages many structures and kills and injures more people in the United States per year, on average, than tornadoes or hurricanes. Many lightning deaths and injuries could be avoided if people would have more respect for the threat lightning presents to their safety.

Lightning deaths are usually caused by the electrical force shocking the heart into cardiac arrest or throwing the heartbeat out of its usual rhythm. Lightning can also cut off breathing by paralyzing the chest muscles or damaging the respiratory center in the brain stem. It takes only about one-hundredth of an ampere of electric current to stop the human heartbeat or send it into ventricular fibrillation. Lightning can also cause severe skin burns that can lead to death if complications from infection set in.

As an indicator of the circumstances involving lightning fatalities, injuries and damage in the United States, consider the following statistics compiled by the National Oceanic and Atmospheric Administration (NOAA) and the National Lightning Safety Institute (NLSI) for the period of 1959-1994:

<u>Location of Lightning Strikes</u>

- 40% are at unspecified locations
- 27% occur in open fields and recreation areas (not including golf courses)
- 14% occur to someone under a tree (not including golf courses)
- 8% are water-related (boating, fishing, swimming, etc.)
- 5% are golf-related (on golf course or under tree on golf course)
- 3% are related to heavy equipment and machinery
- 2.4% are telephone-related
- 0.7% are radio, transmitter and antenna-related

<u>Gender of Victims</u>

- 84% are male; 16% are female

<u>Months of Most Strikes</u>

- July (30%); August (22%); June (21%)

<u>Most Likely Time Period of Reported Strikes</u>

- 2:00 PM – 6:00 PM

Number of Victims

- One victim (91%); two or more victims (9%)

The NLSI has estimated that 85% of lightning victims are children and young men (ages 10-35) engaged in recreation or work-related activities. Approximately 20% of lightning strike victims die, and 70% of survivors suffer serious long-term after-effects such as memory and attention deficits, sleep disturbance, fatigue, dizziness, and numbness.

Lightning can be especially damaging for electrical infrastructure, causing localized power outages and damage to phone lines and communication systems. Computers are also especially vulnerable to lightning strikes. In terms of property losses from lightning, statistics vary widely according to source. The Insurance Information Institute (a national clearinghouse of insurance industry information) estimates that lightning damage amounts to nearly 5% of all paid insurance claims, with residential claims alone exceeding $1 billion. Information from insurance companies shows one homeowner's damage claim for every 57 lightning strikes. The NLSI has estimated that lightning causes more than 26,000 fires annually, with damage to property exceeding $5-6 billion. Electric utility companies across the country estimate as much as $1 billion per year in damaged equipment and lost revenue from lightning. The Federal Aviation Administration (FAA) reports approximately $2 billion per year in airline industry operating costs and passenger delays from lightning. Because lightning-related damage information is compiled by so many different sources, using widely varying collection methods and criteria, it is difficult to determine a collective damage figure for the U.S. from lightning. However, annual lightning-related property damages are conservatively estimated at several billion dollars per year, and those losses are expected to continue to grow as the use of computers and other lightning-sensitive electronic components becomes more prevalent.

Lightning-Related Impacts on Michigan

Unfortunately, lightning has taken a tremendous toll on Michigan's citizens in terms of injury and loss of life. According to National Weather Service records through the mid-2000s, Michigan had incurred 101 lightning deaths, 711 lightning injuries, and 810 lightning casualties (deaths and injuries combined) – consistently ranking it near the top of the nation in all three categories. During the period 1959-1995 (the last period for which composite statistics were available), Michigan was ranked 2nd nationally (behind Florida) in lightning injuries, 12th nationally in lightning deaths, and 2nd nationally (again, behind Florida) in lightning casualties. Undoubtedly, the fact that Michigan is an outdoor recreation-oriented state contributes heavily to its high lightning death and injury tolls. As the following tables indicate, Michigan's lightning deaths and injuries were fairly consistent with the national trends in terms of the location of deadly or injury-causing strikes. More recent data suggests some improvement in Michigan's statistics, ranking it #13 in number of lightning deaths (11) between the years 1998 and 2008.

Lightning-Related Deaths in Michigan: 1959-July 2005

	LIGHTNING DEATHS: 101	
Number of Deaths	**Location**	**Percent of Total**
29	Open fields, ball fields	29%
26	Under trees (not golf)	26%
11	Boats / water-related	11%
10	Golf course	10%
4	Near tractors / heavy equipment	4%
2	At telephone	2%
19	Other location / unknown	19%

Source: Storm Data, National Climatic Data Center

Lightning History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Lightning Events	Days with Event	Total property damage	Injuries	Deaths
Washtenaw	20	18	$1,820,000	4	1
Wayne	20	16	$557,000	18	3
.Livingston	12	12	$1,844,000	1	
Oakland	39	33	$2,318,000	5	1
Macomb	25	19	$2,927,000	7	
5 County Metro region	23 avg.	20 avg.	$9,466,000	35	5
Berrien	3	3	$840,000	1	
Cass					
St. Joseph	5	5	$30,000	2	1
Branch					
Hillsdale	1	1			1
Lenawee	18	14	$880,000		1
Monroe	8	7	$143,000	2	
.Van Buren	2	2	$200,000	2	
Kalamazoo	3	3	$20,000	10	
Calhoun	1	1	$11,000		
Jackson					
.Allegan					
Barry	1	1		1	
Eaton					
Ingham					
.Ottawa	3	3	$60,000	1	
Kent	3	3	$1,000,000		
Ionia	1	1		1	
Clinton					
Shiawassee	6	6	$225,000	1	
Genesee	14	14	$220,500	11	1
Lapeer	9	6	$1,328,000	4	
St. Clair	6	6	$28,000	1	
.Muskegon	1	1	$40,000		
Montcalm	1	1		4	
Gratiot					
Saginaw	7	6	$202,500		
Tuscola	1	1	$100,000		
Sanilac	5	4	$145,000		
.Mecosta	2	2	$50,000	4	
Isabella	1	1	$10,000		
Midland	6	6	$70,000		
Bay	5	4	$63,000		
Huron	3	3	$535,000		
34 County S Lower Peninsula	3 avg.	3 avg.	$6,201,000	45	4

Continued on next page…

Part 2 of Michigan County Lightning History table

.Oceana					
Newaygo	1	1	$100,000		
.Mason					
Lake					
Osceola					
Clare	1	1	$5,000		
Gladwin	1	1		6	1
Arenac	1	1	$500		
.Manistee	1	1			
Wexford	1	1			
Missaukee	3	3	$1,000	2	
Roscommon	2	2	$55,000		
Ogemaw	1	1			
Iosco	3	3	$15,000	6	
.Benzie	1	1			
Grand Traverse	6	4	$170,000	1	1
Kalkaska	2	2		1	
Crawford	1	1		1	
Oscoda	2	2		1	2
Alcona					
.Leelanau	2	2	$40,000		
Antrim	2	2	$80,000		
Otsego	4	4	$503,000		
Montmorency					
Alpena	1	1		1	
.Charlevoix	1	1			
Emmet	1	1	$4,000		
Cheboygan	2	2	$75,000	1	
Presque Isle	2	2	$4,000		
29 Co N Lower Pn	1.5 avg.	1.4 avg.	$1,052,500	20	4
Gogebic	2	2		1	1
Iron	1	1	$50,000		
Ontonagon					
Houghton	2	2	$25,000		
Keweenaw					
Baraga					
.Marquette	4	4	$41,000		
Dickinson	3	3	$171,000		
Menominee					
Delta					
Schoolcraft					
Alger	2	2		3	1
.Luce	1	1	$70,000		
Mackinac	1	1	$150,000		
Chippewa	1	1	$2,800		
15 Co Upp.Pen	1.1 avg.	1.1 avg.	$509,800	4	2
MICHIGAN TOTAL	291	177	$17,229,300	104	15

Although Michigan's counties experience from about 20 to 40 thunderstorm days per year, there are a smaller number of known damaging lightning events per year (about 16 such events per year, on average). Michigan's average deaths from lightning are approximately 1 per year, and injuries average about 6 per year. Property damage from major events totals over $17 million since 1996 – averaging nearly $1 million per year. (Data from the National Climatic Data Center have been used to calculate these statistics.) Although an analysis by Global Atmospherics, Inc. had determined that Southwestern Michigan has the highest rate of lightning strikes, with a strike ratio of 4 flashes/km²/yr, the Southeastern part has a much greater rate of damaging lightning events, as shown in the NCDC summary tables on the previous pages. For comparison, the Global Atmospherics study determined that locations south of Midland have strike ratios of 3 flashes/km²/yr, and areas north of Midland have strike ratios of 2 flashes/km²/yr, including the Upper Peninsula. In terms of NCDC damaging incidents, though, southeast Michigan counties average at least 1 damaging event per year, but the rest of the state averages about one-tenth of this rate. The data reveals some correlation between urbanized land uses and lightning vulnerability, which makes sense from the perspective that a location that is hit in an urban area is more likely to have humans and property in or near that location, to be harmed. But there is also a greater incidence of lightning damage specifically within the southeastern counties, as a result of weather patterns and not just the level of development present there.

Lightning-Related Injuries in Michigan: 1959-July 2005

	LIGHTNING INJURIES: 711	
Number of Injuries	**Location**	**Percent of Total**
243	Open fields, ball fields	34%
104	Under trees (not golf)	15%
35	Golf course	5%
26	Boats / water-related	4%
19	At telephone	3%
20	Near tractors / heavy equipment	3%
264	Other location / unknown	37%

Source: Storm Data, National Climatic Data Center

Because it is virtually impossible to provide complete protection to individuals and structures from lightning, this hazard will continue to be a problem for Michigan's residents and communities. However, lightning deaths, injuries, and property damage can be reduced through a combination of public education, human vigilance, technology, proper building safety provisions, and simple common sense.

Large outdoor gatherings (e.g., sporting events, concerts, campgrounds, fairs, festivals, etc.) are particularly vulnerable to lightning strikes that could result in many deaths and injuries. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early detection, monitoring, and warning of approaching thunderstorms. Early detection, monitoring, and warning of lightning hazards, combined with prudent protective actions, can greatly reduce the likelihood of lightning injuries and deaths. In addition, close coordination between event organizers, local emergency management officials, and response agencies (i.e., police, fire, emergency medical care) can help prevent unnecessary (and often tragic) delays and mistakes in rendering care should a lightning incident occur.

Impact on the Public

Lightning has a discouraging effect on outdoor activities, and has also caused casualties (including death) and severe property damage, including the ignition of structural fires and wildfires, which in turn present serious additional risks and harm to the public and its property. Electrical and communications infrastructure can be affected by lightning strikes, causing widespread inconvenience and, in some cases, life-threatening impairment of needed medical equipment and emergency response.

Impact on Public Confidence in State Governance

When lightning causes infrastructure failure, a question may be raised about the adequacy of that infrastructure, its maintenance, and its design and regulation. In events that require mass sheltering, such as schools or large gatherings (e.g. a county fair or community-sponsored event), the ability of local and state government to adequately plan for severe weather is often vital to the success of such events, which themselves are often important for various sectors of the local and state economy. Citizen discontent and media-exacerbated controversies have arisen from situations in which inadequate planning was evident, or provisions for public sheltering were inadequate.

Impact on Responders

Responders tend to be working outdoors in conditions from which most residents are taking shelter. Although special training and safety precautions have usually been taken (e.g. for line-repair workers), nevertheless, responders are more exposed to and at-risk from lightning. This makes the use of various equipment more difficult and inhibits the ability of responders to work safely outdoors.

Impact on the Environment

Trees can be blown apart completely if struck by lightning, or have branches and bark broken off that can scar and even kill them. Lightning can cause trees and natural vegetation to catch fire, and large wildfires (q.v.) can be devastating upon an area's short-term ecological condition. Dry lightning is lightning that occurs with no precipitation at ground level, and this type of lightning is the most common natural cause of wildfires. Humans and wildlife can both be killed or injured when struck by lightning, and smoke from wildfires is unhealthy to breathe.

Significant Lightning Incidents

As one might expect in a state with a high number of lightning deaths and injuries, lightning incidents involving one individual are fairly common in Michigan. However, lightning incidents involving groups of individuals also take place. Over the past 35 years, numerous lightning incidents in Michigan have resulted in multiple injuries:

<u>Significant Lightning Incidents in Michigan</u>

August 23, 1975 – Leslie (Ingham County)

Ninety people were injured, one seriously, when lightning struck a campground during a severe thunderstorm.

June 20, 1979 – Camp Grayling (Crawford County)

Forty-five National Guardsmen were injured and three of them hospitalized when lightning struck a mess tent during a training mission.

July 7, 1994 – Potterville (Eaton County)

Lightning struck a swimming lake at Fox Memorial Park near Potterville, injuring 22 people (one critically). This strike seemingly came from "out of the blue." That is, there was not a storm actually overhead when it occurred. This is why waters need to be evacuated when there is <u>any</u> indication of lightning nearby.

June 21, 1995 – Ishpeming (Marquette County)

Although no one was injured in this event, a lightning strike caused a fire that destroyed a 100-year old church in downtown Ishpeming, with damages estimated at over a million dollars. Lightning also destroyed the chimney of a downtown house there, during the same storm event.

July 18, 1996 – Gladwin (Gladwin County)

A single bolt of lightning from a distant thunderstorm struck and killed the pitcher in a men's league softball game. Several in the infield were knocked to the ground by the lightning and three were taken to the hospital that day.

June 21, 1997 – Otisville (Genesee County)

After lightning struck a building that was housing a children's event, eight children were taken to the hospital with complaints of numbness and tingling. Fortunately, none of the injuries appeared to be serious.

July 26, 1997 – Farmington Hills (Oakland County)

$750,000 in damage was caused when lightning started a fire in a two-story apartment building.

September 19, 1997 – Southern Lower Peninsula (Midland, Van Buren, Barry, and Kalamazoo Counties)

Lightning struck a farm near Coleman (Midland County), killing 4 horses and doing $10,000 in damage. Lightning also damaged 2 houses in Waterford Township (Oakland County) and an apartment building in Westland (Wayne County). The South Haven Community Hospital (Van Buren County) received a direct lightning strike on its radio tower, disabling communications there ($200,000 damage). A young boy received minor injuries at Hastings (Barry County) when lightning struck near him. Lightning started a house fire in Climax Township (Kalamazoo County), resulting in $20,000 of damage.

June 16, 1998 – Southern Lower Peninsula (Wayne, Washtenaw, and Kent Counties)

A severe thunderstorm developed and a great amount of lighting was produced. A man was killed by lightning when walking to his car in Detroit, and a woman and boy were injured by a lightning strike at a Little League game in Taylor (Wayne County). A transmitting antenna for a radio station in the Hudson Mills area (Washtenaw County) was struck and had to be replaced (about $100,000 damage). A Livonia residence suffered significant damage from a lightning strike (about $2,000 in damage). In Alto (Kent County), lightning started a fire that destroyed a new educational building at a church.

July 21, 1998 – Southern Lower Peninsula (Muskegon, Kent, Macomb, and Wayne Counties)

Severe thunderstorms brought severe winds and frequent lightning to both the east and west parts of the southern Lower Peninsula. In the west, the counties of Muskegon, Kent, and Ottawa suffered more than a half-million dollars of damage from lightning strikes, which caused several major fires. In Muskegon County, lightning caused an attic fire in a house ($40,000 damage) in Muskegon Township, a fire in a storage building in Egelston Township, and power outages that affected 7,500 persons. In Kent County, more than $500,000 in damage resulted from a lightning-caused fire that heavily damaged an apartment building in Grand Rapids, destroying six apartments on the top floor and damaging at least 10 additional apartments when the roof caved in. 15,000 homes lost electricity throughout the Grand Rapids metro area, mostly caused by lightning strikes. The southeastern part of the state was even more heavily impacted by these thunderstorms, resulting in state and federal disaster declarations in Wayne and Macomb County. The storms produced over 4,300 cloud-to-ground lightning strikes, some of which caused fires that destroyed a house and an apartment building, leaving 16 persons homeless and causing $275,000 in damage in Sterling Heights (Macomb County). In Waterford Township (Oakland County), a woman was hospitalized after being struck by lightning in a park.

August 10, 1998 – Brighton (Livingston County)

Thunderstorm-produced lightning struck a store northwest of Brighton. The resulting fire destroyed the building ($1.5 million in damage).

May 11, 2000 – Northville (Wayne County)

Lightning struck at a soccer field as a group was headed for shelter, knocking several persons down and requiring a 12-year-old boy to be hospitalized. Later that evening, lightning struck a tree in Dearborn Heights, and a man working nearby was struck by a limb from the tree, resulting in injuries which hospitalized him.

May 18, 2000 – Detroit Metro Airport (Wayne County)

Lightning struck the steel superstructure of a new terminal under construction at Detroit Metropolitan Airport, injuring nine workers (two requiring hospitalization).

July 27-28, 2000 – Southeast Michigan (Macomb, Lapeer, Sanilac Counties)

Near Romeo (Macomb County), a lightning strike started a fire that destroyed an automall on July 28 ($1 million damage). The previous day, lightning caused a fire that destroyed a manufacturing building and damaged a nearby company structure in Dryden (Lapeer County, $650,000 damage). In the Sandusky area (Sanilac County), a lightning-produced fire partially destroyed a barn ($15,000 damage).

December 11, 2000 – Ann Arbor (Washtenaw County)

Northwest of Ann Arbor, $1.1 million in property damage resulted when lightning caused a large home to be destroyed in the middle of a winter storm emergency.

June 12, 2001 – Benton Harbor (Berrien County)

Lightning struck an apartment complex in Benton Township, resulting in 35 residents being evacuated. The total property damage from the fire was $800,000.

September 19, 2002 – Ann Arbor (Washtenaw County)

One roofer was killed and two others were badly injured in Ann Arbor when they were hit by lightning during a thunderstorm.

July 4, 2003 – Oscoda (Iosco County)

During thunderstorms, lightning destroyed a large business sign whose fragments damaged nearby vehicles. One car had four occupants injured by shattering glass, and damages were estimated at $10,000.

July 16, 2005 – Macomb Township (Macomb County)

One house was completely destroyed by fire as the result of a lightning strike. Five additional house fires started in the areas of 22 and 23 Mile Roads, due to other lightning strikes from the same storm event. Total damages amounted to about a million dollars.

July 17, 2006 – Southeastern Michigan (Saginaw and Wayne Counties)

Intense thunderstorms produced lightning that seriously damaged a Church bell tower in Saginaw ($106,000 damage), and caused one injury and one death in the central-city area of Wayne County, when a couple sought refuge outdoors by going under a tree, which was then struck during the storm.

July 22, 2009 – Big Rapids (Mecosta County) and Gaylord (Otsego County)

At 8:45 am, a non-severe thunderstorm caused lightning to strike pine trees at Ferris State University, as four construction workers were standing nearby. All four workers were injured. That same afternoon, a lightning strike 1 mile north of Gaylord ignited a fire that rapidly spread through the Alpine Haus apartment complex, destroying it and leaving 52 persons without housing. Fortunately, no one was hurt in the apartment fire, but damages were estimated at $500,000.

July 15, 2010 – Vestaburg (Montcalm County)

Lightning struck four young persons between 9 and 18 years of age at a baseball diamond near Vestaburg. Fortunately, all survived the incident, but their injuries required special emergency care, including emergency medical flights to the appropriate care facilities.

September 21, 2010 – Kent County

Various fire departments reported that about a dozen house fires were ignited, in an area from Ada south to Caledonia, by lightning strikes produced by severe storms during the late afternoon.

April 26, 2011 – Portage (Kalamazoo County)

Nine people were injured and sent to the hospital (one severe) after lightning struck at a soccer field in Westfield Park (Portage). One man went into cardiac arrest but was able to be treated at a nearby hospital and released. The ages of the victims ranged from 12 to 41.

September 3, 2011 – Ann Arbor (Washtenaw County)

Michigan Stadium (with a capacity of over 100,000 people) was evacuated during a football game, due to a thunderstorm. The game was eventually called off in the third quarter, due to the strong winds, heavy downpours of rain, and several lightning strikes.

June 18, 2012 – Ellsworth (Antrim County)

Lightning struck a home in Banks Township, and the resulting fire destroyed the home (causing about $80,000 in damage).

Programs and Initiatives

Unfortunately, lightning prevention or protection, in an absolute sense, is impossible. However, the consequences of lightning strikes have been diminished (both in terms of deaths and injuries and property damage) through the implementation of the following programs and special initiatives:

National Weather Service Education

The National Weather Service issues severe thunderstorm watches and warnings when there is a threat of severe thunderstorms. However, lightning, by itself, is not sufficient criteria for the issuance of a watch or warning (every storm would require a watch or warning). The National Weather Service has an extensive public information program aimed at educating citizens about the dangers of lightning and ways to prevent lightning-related deaths and injuries.

Severe Weather Awareness Week

Each spring, the Emergency Management and Homeland Security Division, Michigan Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Severe Weather Awareness Week. This annual public information and education campaign focuses on such severe weather events as tornadoes, thunderstorms, hail, high winds, flooding and lightning. Informational materials on lightning hazards are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Lightning Protection for Structures

The National Lightning Safety Institute (NLSI) has identified a systematic lightning hazard mitigation approach that can be followed to protect structures from lightning damage. That approach attempts to mitigate both the direct and indirect effects of lightning strikes through the application of appropriate structural safety improvements, as identified in a comprehensive lightning safety analysis. Full details of this mitigation approach can be obtained on a web page for NLSI.

National Lightning Detection Network

Despite advancements in electric power system design and equipment, lightning continues to be the single largest cause of outages on electrical distribution and transmission lines. To help combat that problem, the National Lightning Detection Network (NLDN) – a technologically advanced lightning location system operated by a private company in Phoenix, Arizona – was invented. The NLDN helps electric utilities make effective decisions regarding line maintenance priorities, crew dispatch, and future design and placement of utility transmission lines and lightning protection. NLDN lightning data is available in both real-time and archival format (1989-present). The lightning information from NLDN might lead to significant savings in utility maintenance and construction budgets, improved design and placement of future transmission and distribution infrastructure, and reduced outages due to lightning-related damage. Data from the NLDN can also be used to improve the safety of participants at outdoor events such as golf tournaments, air shows, fairs and outdoor festivals, and sporting events and concerts at outdoor stadiums and racetracks.

Local Lightning Detection Systems

Local lightning detection systems are increasingly being installed at golf courses, parks, pools, sports fields and stadiums, and other outdoor venues. These detection devices monitor electrical activity in the atmosphere and identify when favorable lightning conditions exist by activating a warning light or horn. That early warning can give local officials the time necessary to clear outdoor areas before actual lightning strikes occur.

Lightning Risk Calculator for buildings

Since lightning is an isolated phenomenon that causes great damage to a limited area and minimal damage to the structures adjacent to the lightning strike, it is necessary to determine lightning risks for some of the important buildings in your community. This is in addition to the general risk assessment of lightning strikes per year for a given county in the state. One way to calculate the risk of lightning strikes for a type of structure in your area is by using an on-line "Lightning Risk Calculator" from HLP Systems, Inc. at http://www.apltd.com/cgi-local/aestiva/start.cgi/riskhlp.htm. This lightning calculator examines the risk associated with various types of building sizes, materials, heights, uses, and roof types. It is not a foolproof source for assessing lightning risks for buildings in your community, but it does provide a simple way to begin to look at how some areas may be affected by lightning strikes.

Mitigation Alternatives for Lightning

- Increased coverage and use of NOAA Weather Radio.
- Public early warning systems and networks.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)
- Using surge protectors on critical electronic equipment.
- Installing lightning protection devices on the community's communications infrastructure.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of lightning conditions), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the lightning hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes lightning information as it has been reported in local hazard mitigation plans. For a brief summary of lightning-related information from that section of this plan, it will here be noted that lightning was identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Branch, Calhoun, Clare, Delta, Genesee, Huron, Lapeer, Mackinac, Ogemaw, Roscommon, Shiawassee, Washtenaw (12 counties).

Severe Winter Weather Hazards

Severe winter weather hazards include snowstorms, blizzards, extreme cold, and ice and sleet storms. As a northern state, Michigan is vulnerable to all of these winter hazards. Most of the severe winter weather events that occur in Michigan have their origin as Canadian and Arctic cold fronts that move across the state from the west or northwest, although some of the most significant winter storms have their origins from the southwest, in combination with Arctic air masses. As the maps on the following pages show, Michigan averages moderate to heavy snowfall and extreme cold, averaging 90-180 days per year below freezing in the Lower Peninsula, and over 180 days below freezing in most of the Upper Peninsula. (For record snowfall amounts and a description of Michigan's three general "regions," please refer to the relevant table and text in the Introduction to the Weather Hazards section in this plan.)

The snowstorms and ice and sleet storms sections that follow provide greater detail on those particular severe winter weather hazards. The extreme temperatures section provides a more detailed overview of the severe cold temperatures hazard.

Winter storm hazards plague Michigan annually from November to March, with the state being vulnerable to snowstorms and ice and sleet storms. No area of the state is immune to severe winter conditions that can clog or paralyze the transportation network, cause widespread power outages, and slow normal daily activities to a standstill. Each community should be prepared for the harsh landscape created by snow and ice extremes. One way to understand the approaching risks of winter weather comes in the form of daily forecasts, and winter watches and warnings from the National Weather Service. The website for the NWS is www.crh.noaa.gov, which covers all regions in Michigan. To obtain recent county-level historical data since 1993 for both severe snowstorms and ice and sleet storms, visit the National Climatic Data Center's Storm Event website,
http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms

Winter Weather Hazards (General)

- Increased coverage and use of NOAA Weather Radio.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines, where appropriate.
- Establishing heating centers/shelters for vulnerable populations.

Emphasis in Local Hazard Mitigation Plans

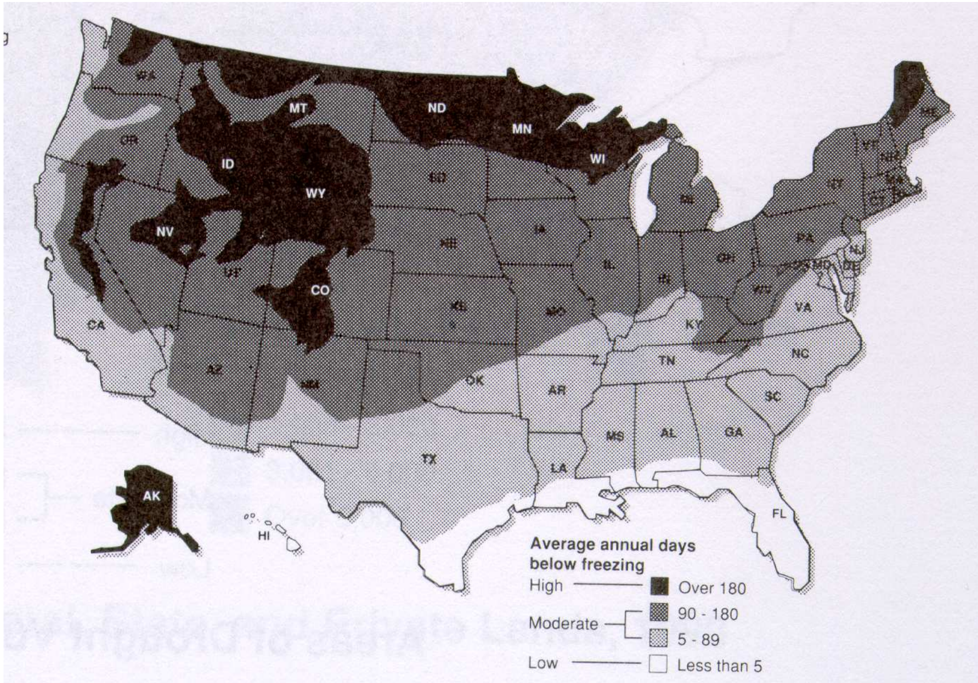
Severe Winter Weather was identified as one of the most significant hazard in local hazard mitigation plans for the following counties: Allegan, Alpena, Antrim, Barry, Bay, Benzie, Berrien, Branch, Calhoun, Cass, Charlevoix, Cheboygan, Chippewa, Delta, Emmet, Genesee, Grand Traverse, Gratiot, Hillsdale, Huron, Ionia, Isabella, Kalamazoo, Kalkaska, Kent, Lake, Lapeer, Leelanau, Luce, Macomb, Manistee, Marquette, Mason, Mecosta, Menominee, Midland, Missaukee, Monroe, Montcalm, Montmorency, Muskegon, Newaygo, Oceana, Ogemaw, Osceola, Oscoda, Otsego, Ottawa, Roscommon, Saginaw, Schoolcraft, Shiawassee, Tuscola, Van Buren, and Wexford.

To obtain recent county-level historical data since 1993 for both severe snowstorms and ice and sleet storms, visit the National Climatic Data Center's Storm Event website,
http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms
and select a profile of your county's major winter storm history. The site has one category for severe "Snow and Ice" storms, but categorizes them separately once a particular county's information is accessed.

The following two sections will outline the risks for ice, sleet, and snowstorms.

Average Annual Days Below Freezing in the U.S.

Source: Council of State Governments; Federal Emergency Management Agency



Ice and Sleet Storms

A storm that generates sufficient quantities of ice or sleet to result in hazardous conditions and/or property damage.

Hazard Description

Although these two types of winter storms have been combined in this subsection, ice storms and sleet storms are two different phenomena. Ice storms, also known as freezing rain, coat roads, trees, power lines, and buildings with thick, heavy, and slick surfaces. Ice storms are sometimes incorrectly referred to as sleet storms. Sleet is small frozen rain drops (ice pellets) that bounce when hitting the ground or other objects. Sleet storms, which involve small pellets of ice accumulating on surfaces, are less dangerous than ice storms, but still cause potential harm to transportation and electrical systems. Sleet does not stick to trees and wires, but sleet in sufficient depth does cause hazardous driving conditions. Ice storms are the result of cold rain that freezes on contact with a surface, coating the ground, trees, buildings, overhead wires and other exposed objects with ice, sometimes causing extensive damage. When electric lines are downed, power may be out for several days, resulting in significant economic losses and the disruption of essential services in affected communities. Massive traffic accidents and power outages from downed tree limbs and utility lines are common when an ice storm occurs.

Ice storms usually have a regional effect and may influence all corners of Michigan. Groups of counties are usually affected instead of just one county. Often, ice storms are accompanied by snowfall, in which the ice is camouflaged and covered up by snow, creating treacherous transportation conditions. Both storms occur when the temperature is close to 32°F, but are far more severe when the temperature is in the 20s. The southern parts of the state have annual winter temperatures closer to 32°F, so the prevalence for ice and sleet storms seems more likely there than in the northern areas of the state. Events tend to be more severe when they occur as temperatures lower into the 20s.

Hazard Analysis

The table below illustrates the frequency distribution of ice and sleet storms in Michigan for the period 1970-July 2007. Approximately 81% of those storms occurred during the months of January, February, March and April, when conditions are most conducive for the development of ice and sleet. One-quarter of all ice and sleet storms in the period occurred during the month of March, and more than a quarter occurred in January.

By observing winter storm watches and warnings, adequate preparations can usually be made to reduce the impacts of ice and sleet conditions on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear broken tree limbs from roadways, are the primary challenges facing community officials. Severe ice and sleet storms can affect every Michigan community. Ice storms usually have a regional effect and groups of communities are usually affected instead of just one community. Therefore, every community should plan and prepare for these emergencies. MSP/EMHSD staff has not yet found specific documentation on sleet and ice storms in the state to verify different vulnerabilities in different areas of the state. The southern parts of the state have annual winter temperatures closer to 32°F, so the prevalence for ice and sleet storms seems more likely there than in the northern areas of the state. Planning and preparedness efforts should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as debris removal equipment and services. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Frequency Distribution of Ice and Sleet Storms
in Michigan: 1970 – July 2007

JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
17	**10**	**14**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**9**	**59**
29%	**17%**	**24%**	**10%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**5%**	**15%**	**100%**

Source: National Weather Service; Storm Data, National Climatic Data Center (percentages are rounded off)

Ice/Sleet Storm History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	**Ice/Sleet Events**	**Tot. property damage**	**Tot. crop damage**	**Deaths**	**Injuries**
Washtenaw	7	$3,400,000			1
Wayne	8	$5,000,000			1
.Livingston	7	$2,310,000			
Oakland	8	$104,452,000		1	2
Macomb	8	$54,325,000			
5 Co Metro region	**8 avg.**	**$169,487,000**		**1**	**4**
Berrien	9	$30,000			
Cass	9	$30,000			
St. Joseph	10	$30,000			
Branch	9				1
Hillsdale	9				
Lenawee	8	$2,530,000			
Monroe	8	$4,540,000			
.Van Buren	6	$25,000			
Kalamazoo	6	$75,000			
Calhoun	6	$30,000			
Jackson	6	$30,000			
.Allegan	6				
Barry	6	$25,000			
Eaton	7	$325,000			
Ingham	7	$340,000			
.Ottawa	8	$500,000			
Kent	8	$1,000,000			
Ionia	8	$330,000			
Clinton	7	$330,000			
Shiawassee	8				
Genesee	8	$110,000			
Lapeer	8	$1,075,000			
St. Clair	8	$10,100,000			
.Muskegon	6	$200,000			
Montcalm	8	$200,000			
Gratiot	7	$1,250,000	$5,000		
Saginaw	12	$1,010,000			
Tuscola	9	$20,000			
Sanilac	7	$30,000			
.Mecosta	8	$350,000	$5,000		
Isabella	8	$350,000	$5,000		
Midland	11				
Bay	11				
Huron	8	$25,000			
34 Co S Lower Pen	**8 avg.**	**$24,890,000**	**$15,000**		**1**

Continued on next page…

Part 2 of Ice/Sleet History for Michigan Counties – arranged by region

.Oceana	2	$200,000			
Newaygo	2	$200,000			
.Mason	1	$200,000			
Lake	1	$200,000			
Osceola	4	$450,000	$5,000		
Clare	4	$350,000	$5,000		
Gladwin	3	$60,000			
Arenac	2	$50,000			
.Manistee	4				
Wexford	3				
Missaukee	2				
Roscommon	3				
Ogemaw	3	$5,000			
Iosco	4	$50,000			
.Benzie	4				
Grand Traverse	4				
Kalkaska	4				
Crawford	1				
Oscoda	2				
Alcona	3				
.Leelanau	4				
Antrim	3				
Otsego	3				
Montmorency	3				
Alpena	2				
.Charlevoix	3				
Emmet	4				
Cheboygan	4				
Presque Isle	4				
29 Co N Lower Pen	**3 avg.**				
Gogebic	3				
Iron	3				
Ontonagon	3				
Houghton	1				
Keweenaw	2				
Baraga	3				
.Marquette	4				
Dickinson	5				
Menominee	4				
Delta	4				
Schoolcraft	4				
Alger	4				
.Luce	5				
Mackinac	3				
Chippewa	3				
15 Co Upper Pen					
MICHIGAN TOTAL	294	$196,142,000	$25,000	1	5

There is an average of about 15 significant storm events in Michigan each year (not all of which are direct damaging on a community level). Many events are multi-county events, with damages from a wide area merely estimated within each country, and therefore the state and county totals in the table may not add together neatly. Many ice storm deaths are actually caused by automobile accidents, heart attacks from overexertion, downed power lines, carbon monoxide poisoning, and other secondary effects that may be difficult to distinguish from other causes. In terms of property damage, major ice storm events have, according to NCDC records, caused about $200 million in damages since 1996 (averaging about $10 million per year), and the April 2003 ice storm was particularly severe, reportedly causing half that amount in itself. Geographically, a clear pattern is evident in the table—these events are most frequent in the southern Lower Peninsula, and become much less common in northern parts of the state. Damages from ice/sleet hazards were not even reported in NCDC records for the Upper Peninsula or the northernmost counties in the Lower Peninsula. The records indicate property and crop damage only in Michigan counties located south of the 45th Parallel. However, it is assumed that any events listed in NCDC were serious enough that they had the potential to do damage; the lack of damage reports for the past 20 years should not suggest that ice/sleet damage is impossible, but merely less likely according to the historical records.

Impact on the Public
Ice and sleet storms tend to cause power or other infrastructure failures that interfere with residents' activities, comfort, and safety (often through the impact of infrastructure failures on needed medical and emergency response capabilities). Direct physical effects may include frostbite, hypothermia, and other medical conditions, and thus require some citizens to be provided with warm clothing and shelter. Certain types of building designs are susceptible to structural failure from the accumulation of ice or snow on their roofs. Traffic efficiency and road capacity tends to be impeded by these weather events, which cause a large increase in the risks involved in all modes of travel. Injurious accidents may include simple pedestrian falls (due to the difficulty of balancing and walking on ice-coated surfaces), or large-scale transportation accidents (such as multi-car interstate pileups).

Impact on Public Confidence in State Governance
For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the ice or sleet event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away ice and sleet from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders
Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Icy conditions make various travel and outdoor operations treacherous.

Impact on the Environment
Freezing rain drops (sleet) and dangerous ice storms coat surfaces with layers of ice and can also affect the environment. Ice storms can damage trees, as the weight of accumulated ice brings down limbs and branches, or even entire trees. When soil is not frozen, ice loads can cause root damage to forest trees. An ice coating over widespread forest lands can destroy natural forest vegetation and disrupt species' habitats, species composition, and forest land diversity. Dried dead trees may be more prone to fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become breeding areas for beetles and other pests that can harm the healthy green trees. Floods often occur when ice melts, and can cause environmental effects (as described in the flooding section).

Climate Change Considerations
Climate change effects seem likely to cause an increase in the number of ice and sleet storm events, at least across the southern part of Michigan. The reason involves average temperatures in and around the winter months that are closer to the freezing point, at which ice and sleet events typically occur. Instead of winter arriving and precipitation remaining as snow, Michigan has been seeing more thawing episodes, followed by refreezes which can cause treacherous ice cover upon frozen surfaces, weight down cables and tree branches, and cause breakages which lead to infrastructure failures. Even though Michigan's winter season has been shortening over time, winters remain

hazardous because the increasing level of precipitation more often takes the form of major snow events, and provides a lot more moisture for refreezing after warmer thawing periods.

Significant Ice and Sleet Storms in Michigan since 1976

March 2-7, 1976 – Central Lower Michigan

During the period from March 2-7, 1976 an ice storm with accompanying high winds and tornadoes struck a 29 county area in the central Lower Peninsula. This storm, one of the worst to ever hit the state, caused over $56 million in damage, and widespread power outages. The storm impacts were so severe that a Presidential Major Disaster Declaration was granted for the 29 affected counties, to assist in the recovery from the storm.

April 8, 1979 – Southern Lower Michigan

On April 8, 1979 an ice storm struck Lower Michigan south of a line from Grand Haven to Bay County. The storm left 240,000 utility customers without power for several days. In addition, numerous injuries resulted from the downed power lines.

January 1, 1985 – Southern Lower Michigan

On January 1, 1985 a severe ice storm struck a 13 county area in the southern Lower Peninsula. Freezing rain accumulating up to one inch in thickness downed tree limbs, trees and power lines, blocked roads, and caused widespread power outages. There were three deaths and eight injuries directly related to the ice storm. Approximately 13,000 homes and 260 businesses sustained damage or were destroyed, with losses estimated at nearly $25 million. Another 160 businesses lost inventory as a result of the storm damage and power outages. Over 430,000 electrical customers were without power, some for as long as 10 days. At the height of the power outage, 28 public shelters were opened to provide shelter to nearly 1,000 residents without power or heat. Several nursing homes and adult foster care facilities had to be evacuated due to the loss of power and heat. Total public and private damage from this ice storm was estimated at nearly $50 million. A Governor's Disaster Declaration was issued to mobilize state resources to assist in the storm response and recovery.

March 13-14, 1997 – Central and Southeast Michigan

In the late evening hours of March 13, 1997 an ice storm struck the central and southeastern Lower Peninsula, causing widespread power outages, icy roads, downed trees and numerous school closings. Many of the counties in the southern third of Michigan were impacted by the storm. North of Detroit, nearly all the precipitation fell in the form of freezing rain, in amounts ranging from 0.8 to 1.5 inches. Farther south, precipitation amounts ranged from 1.5 to nearly 2.5 inches. Macomb County damages amounted to about $4 million, Lenawee County totaled $1 million, as did Monroe County. Washtenaw damage tallies were $3 million, Oakland had $4 million in damage, as did Wayne County, and Livingston County suffered $2 million in damages. In the storm's aftermath, 514,000 Detroit Edison and Consumers Energy electrical customers were without power, several thousand of whom went without for as long as 4 days. Major outages occurred in Jackson, Kalamazoo, Cass, Branch, St. Joseph and Calhoun counties, as well as in Lansing. Many local communities opened shelters to accommodate residents unable to remain in their homes due to the lack of power. Response efforts were severely hampered by snow and windy conditions the following day. In addition to fallen power lines, falling trees damaged dozens of cars and houses throughout the area. Most schools were closed, and there were numerous auto accidents.

April 3-5, 2003 – West and Central Lower Michigan

A major ice storm affected much of southern Lower Michigan, causing hundreds of thousands of people to lose power. The weight of the ice brought down thousands of trees and limbs and hundreds of power lines. Many people across the area lost power for several days and some who lived in outlying areas were without power for a week. The ice storm resulted in several million dollars' worth of damage across the area. Most of the counties across the central and southern Lower Peninsula received a total of ½ to 1½ inches of ice. It was one of the biggest ice storms to affect lower Michigan in the previous 50 years. Damage totals amounted to $1 million in Kent County, $1 million in Lapeer County, $10 million in St. Clair County, $50 million in Macomb County, and $100 million in Oakland County, where 1 death and 2 injuries also occurred (due to falling trees and branches). Additional casualties stemmed from traffic accidents—about two dozen injuries and one death, the latter from a car skidding into a ditch filled with water. Three persons also died from carbon monoxide poisoning, due to the use of poorly ventilated generators.

February 16, 2006 – Central Lower Michigan

A major ice storm affected much of central Lower Michigan. There were numerous reports of ice accumulations up to one inch. This glazing caused widespread tree damage and thousands of power outages. Some people were without power for several days, resulting in the opening of numerous temporary shelters due to the extreme cold in the wake of the ice storm. Total damages were in excess of $2 million. $1 million in damage took place in Gratiot County, and $1 million in Saginaw County.

January 14-15, 2007 – Southern Lower Michigan

A major ice storm affected an area from the extreme southwestern part of Lower Michigan northeast into the Flint and Detroit metro areas. There were numerous reports of ice accumulations up to one half inch. This glazing caused widespread tree damage and over 150,000 structures to be without power. Total damages exceeded $2 million.

March 1-2, 2007 – Southeast Michigan

In Huron County, a high-impact ice storm resulted in ice accumulations up to 3 inches thick on power lines and trees. Other "Thumb" counties were also hard-hit. Most of the damage occurred between 10 pm on March 1 and 1am on March 2. Strong winds gusted to 50 mph and brought down trees and utility poles over many miles. More than half of Huron County's population was without power, some for up to 6 days. Hundreds sought shelter and were assisted by the American Red Cross. Hundreds of traffic accidents took place, including some that were serious and resulted in 6 injuries and one death. Property damage alone amounted to $1.5 million (mostly in Huron County).

February 20-21, 2011 – Lenawee and Monroe Counties

At the end of a large snowstorm (producing 5 to 10 inches of snow across the majority of southeast Michigan), the snow turned to ice near the Ohio border as a major ice storm occurred. Downed trees and power lines occurred across Lenawee and Monroe Counties, due to ice accumulations of ½ to 1 inch. Power outages lasted for up to 4 or 5 days. Property damage in Lenawee County amounted to $1.5 million, and $3.5 million in Monroe County.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from snowstorms have the dual purpose of also protecting against ice and sleet storms. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

<u>National Weather Service Doppler Radar</u>

The National Weather Service (NWS) has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winter weather events such as ice and sleet storms. Most important, the lead time and specificity of warnings for severe weather have improved significantly.

National Weather Service Watches/Warnings

Sufficient warning can do much to reduce the damage from ice and sleet storms by permitting people to prepare properly. The National Weather Service uses the terms "ice storm," "freezing rain," and "freezing drizzle" to warn the public when a coating of ice is expected on the ground and on other exposed surfaces. The qualifying term "heavy" is used to indicate ice coating which, because of the extra weight of the ice, could cause significant damage to trees, overhead wires, and other exposed objects.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet, at www.weather.gov, where an interactive map can be used.

Winter Hazards Awareness Week

Each fall, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Winter Hazards Awareness Week. This annual public information and education campaign focuses on winter weather hazard events such as snowstorms, blizzards, extreme cold, and ice and sleet storms. Informational materials on winter weather hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Electrical Infrastructure Reliability

One of the major problems associated with ice storms is the loss of electric power. Michigan has had numerous widespread and severe electrical power outages caused by ice storms, several of which have resulted in a power loss to 250,000 – 500,000 electrical customers for several hours to several days at a time. Ice-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by ice, severe winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing ice storm damage caused by falling trees or tree branches. In almost every ice storm, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Often, crews from the area public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

Mitigation Alternatives for Ice and Sleet Storms

- Increased coverage and use of NOAA Weather Radio.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)
- Establishing heating centers/shelters for vulnerable populations.
- Home and public building design and maintenance to prevent roof and wall damage from "ice dams."

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of ice and sleet storm conditions), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the ice and sleet hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes ice and sleet storm information as it has been reported in local hazard mitigation plans. For a brief summary of ice/sleet-related information from that section of this plan, it will here be noted that ice/sleet was identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Alger, Berrien, Cheboygan, Clinton, Delta, Genesee, Grand Traverse, Hillsdale, Jackson, Lake, Lapeer, Lenawee, Marquette, Mecosta, Schoolcraft, Tuscola. (Note: Most local plans did not sufficiently distinguish between ice, sleet, and snowstorms, and so this information should be used as an approximate indicator of local priorities for this hazard.)

Snowstorms

A period of rapid accumulation of snow often accompanied by high winds, cold temperatures, and low visibility.

Hazard Description

As a result of being surrounded by the Great Lakes, Michigan experiences large differences in snowfall over relatively short geographic distances. The average annual snowfall accumulation in different areas ranges from 30 to 200 inches of snow. The highest accumulations are in the northern and western parts of the Upper Peninsula, as some areas of Baraga and Houghton Counties receive over 200 inches of snow per year. In Lower Michigan, the highest snowfall accumulations occur near Lake Michigan and in the higher elevations of northern Lower Michigan. Areas in the northwest portion of the Lower Peninsula average greater than 120 inches of snow annually. On the low end of snowfall totals, areas in the east central and southeastern portions of the state receive less than 50 inches of snow per year. Communities in West Michigan typically receive 60-100 inches of snow.

Blizzards are the most dramatic and perilous of all snowstorms, characterized by low temperatures and strong winds (35+ miles per hour) bearing enormous amounts of snow. Most of the snow accompanying a blizzard is in the form of fine, powdery particles that are wind-blown in such great quantities that, at times, visibility is reduced to only a few feet. Blizzards have the potential to result in property damage and loss of life. Just the cost of clearing the snow can be enormous.

Snowstorms can be very dangerous for a community over a period of days or weeks. Heavy snows can shut down towns and cities for several days if snow is persistent and cannot be cleared in a timely fashion. Pre-planning for snow storage areas will be helpful. Roof failures may occur as the weight of the snow and area of snow cause damage to homes and buildings. Motorists and passengers in cars can be stranded in rural areas and die of exposure because of inadequate preparation for conditions.

Extreme snows are most likely in the Upper Peninsula and the northern sections of Lower Michigan. Areas in the northwest portion of the Lower Peninsula average greater than 120 inches of snow annually. The snow is more extreme in the Upper Peninsula, as some areas of Baraga and Houghton Counties receive over 200 inches of snow per year. On the low end of snowfall totals, areas in the east central and southeastern portions of the state receive less than 50 inches of snow per year. Communities in West Michigan typically receive 60-100 inches of snow. A map appears on the next page.

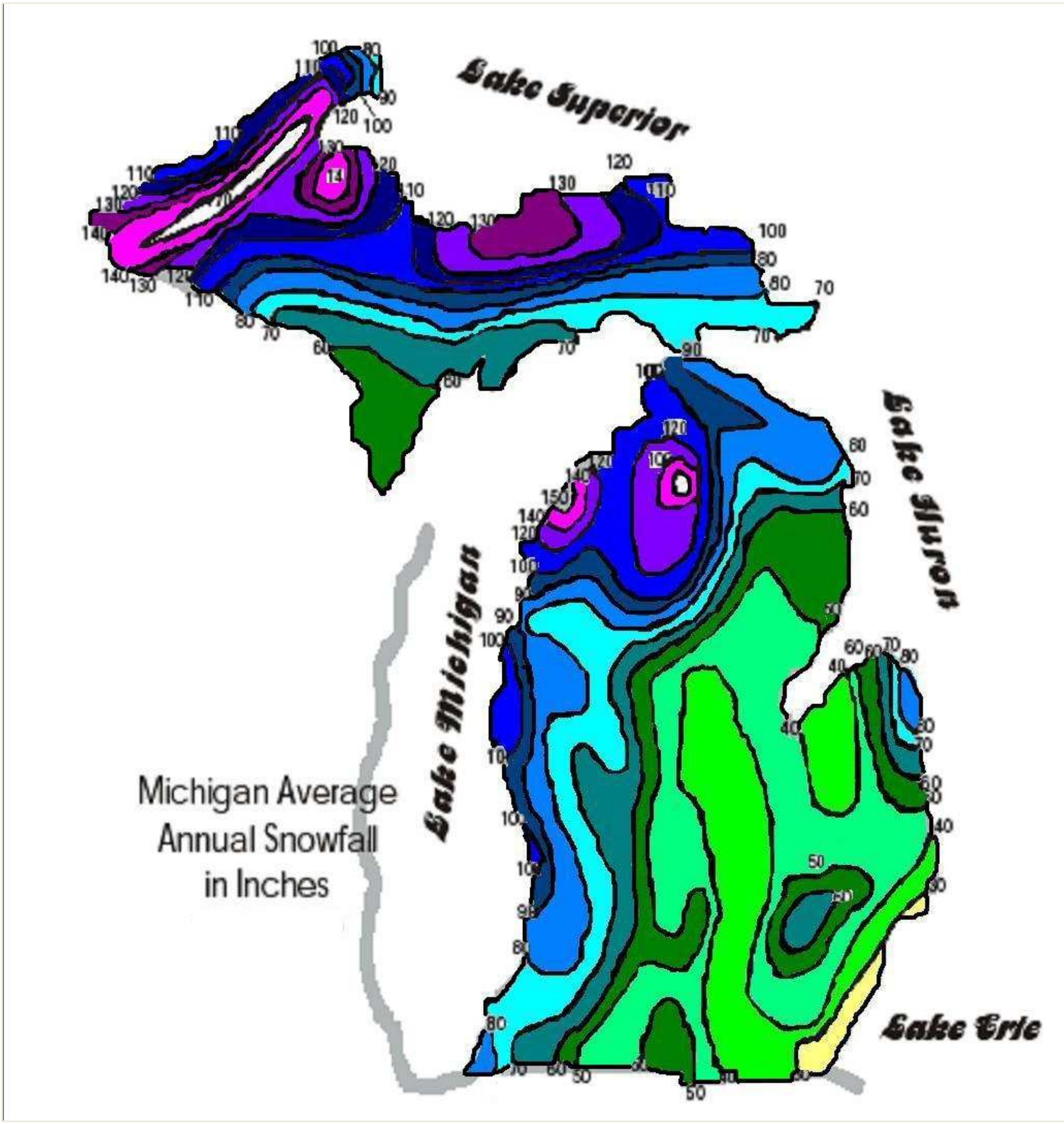
Urban areas can be especially susceptible to outages and problems with snow removal, due to their complexity and limited space for snow clearance and storage. Rural areas may have inaccessible roads for some time but often have residents that are more equipped to independently handling power outages and temporary isolation. Information about snow cover and types, which may be useful either for an analysis of the snowstorm hazard, or in an analysis of snowmelt-related flood risks, may be found at http://www.nohrsc.nws.gov.

Hazard Analysis

The snowfall map before the preceding section shows that the western Upper Peninsula experiences the most snowstorms and snowfall in Michigan each year. The western half of the Lower Peninsula also experiences heavy snowfall and a relatively large number of snowstorms. One reason for this is the "lake effect," a process by which cold winter air moving across Lakes Michigan and Superior picks up moisture from the warmer lake waters, resulting in larger snowfall amounts in the western part of the state.

Michigan Average Annual Snowfall

Source: Michigan Committee for Severe Weather Awareness



Please refer to the table in the Introduction to the Weather Hazards section to find a table of record snowfall amounts at various locations across Michigan, and for a description and comparison of the state's three general "regions," as defined in this document. In general, the snowstorm season of the Southern Lower Peninsula runs from November to April each year. (Although snow occasionally does fall outside of this "season," such snowfall would be comparatively light, rather than the sort of snowstorm event that is here being considered as a hazard.) The snowstorm season in the Northern Lower Peninsula runs from October to May. The snowstorm season for the Upper Peninsula runs from late September to May. This does not mean that all of these months necessarily receive significant snowfall each year. Instead, the "season" denotes the part of each year when a significant snowstorm may occur. A significant snowstorm is here defined as at least several inches of snow accumulation in a single event.

Snowstorm History for Michigan Counties – arranged by region – Jan. 1996 to Oct. 2013
(The Lower Peninsula regions are ordered by "tiers" from south to north, west to east)
Please refer to the Michigan Profile Map section for an explanation of regional divisions

COUNTY or area	Snow Storm Events	Days with Snow Storms	Tot. property damage	Tot. crop damage	Injuries	Deaths
Washtenaw	45	45	$225,000			
Wayne	38	38	$960,000			
.Livingston	47	47	$129,000		3	
Oakland	49	49	$400,000		3	
Macomb	43	43	$170,000			
5 Co Metro region	**44 avg.**	**44 avg.**	**Total $1,884,000**		**6**	
Berrien	83	83	$20,000			
Cass	72	71				
St. Joseph	42	42				
Branch	40	40				
Hillsdale	35	35				
Lenawee	42	40	$505,000			
Monroe	33	33	$45,000			
.Van Buren	111	111	$25,000			
Kalamazoo	73	73	$25,000			
Calhoun	52	52	$2,225,000			
Jackson	47	47	$1,200,000			
.Allegan	130	129	$25,000			
Barry	61	61	$25,000			
Eaton	45	46	$1,025,000			
Ingham	46	46	$1,025,000			
.Ottawa	122	122	$250,000			
Kent	87	87	$50,000			
Ionia	46	46	$25,000			
Clinton	40	40	$1,025,000			
Shiawassee	39	39	$10,000			
Genesee	49	49	$1,650,000		1	
Lapeer	46	46	$10,000			
St. Clair	57	57	$45,000			
.Muskegon	102	102				
Montcalm	58	57	$30,000			
Gratiot	46	45	$25,000			
Saginaw	48	48	$25,000			
Tuscola	46	46				
Sanilac	59	59	$5,000			
.Mecosta	56	55	$40,000			
Isabella	49	48	$290,000			
Midland	45	44				
Bay	46	45	$25,000			
Huron	54	54	$1,500,000			
34 Co S Lower Pen	**59 avg.**	**59 avg.**	**Total $11,150,000**		**1**	

Continued on next page…

Part 2 of Snowstorm History for Michigan Counties – arranged by region

.Oceana	100	99				
Newaygo	69	69	$25,000			
.Mason	99	98				
Lake	71	70	$375,000			
Osceola	56	55	$510,000			
Clare	52	51	$300,000			
Gladwin	35	35				
Arenac	38	38				
.Manistee	72	72	$350,000			
Wexford	57	57	$283,000			
Missaukee	63	63	$185,000			
Roscommon	52	52	$100,000			
Ogemaw	45	45	$50,000			
Iosco	42	41				
.Benzie	79	79	$600,000	$2,000,000		
Grand Traverse	93	93	$612,000	$5,000,000		
Kalkaska	106	106	$290,000			
Crawford	66	66	$255,000			
Oscoda	46	46	$100,000			
Alcona	39	39	$3,000			
.Leelanau	102	102	$653,000	$13,000,000		
Antrim	122	122	$250,000			
Otsego	101	100	$337,000			
Montmorency	48	48	$165,000			
Alpena	55	55	$110,000			
.Charlevoix	110	110	$295,000			
Emmet	91	91	$204,000			
Cheboygan	71	71	$206,000			
Presque Isle	55	55	$258,000			
29 Co N Lower Pen	**70 avg.**	**70 avg.**	**Total $6,516,000**	**$20,000,000**		
Gogebic	167	167	$63,000		1	
Iron	66	66	$605,000			
Ontonagon	200	200	$16,000		2	1
Houghton	44	43				
Keweenaw	160	158				
Baraga	118	117	$6,000			
.Marquette	154	153	$262,000			1
Dickinson	68	68	$20,000			
Menominee	71	71	$7,000			
Delta	94	94	$75,000			
Schoolcraft	19	19				
Alger	192	190	$11,000			
.Luce	119	118	$3,500			
Mackinac	58	57	$50,000			
Chippewa	98	98	$85,000			
15 Co Upp. Pen	**108 avg.**	**108 avg.**	**Total $1,203,500**		**3**	**2**
MICHIGAN TOTAL	**6,261**	**1,038**	**$20,798,500**	**$20,000,000**	**10**	**2**

Michigan had historically seen a major regional or statewide snowstorm approximately every 5 years. Local events are more frequent. Both may currently be increasing (and are projected to increase) due to climate change effects. Total casualties can be difficult to assess because many deaths are caused by automobile accidents, heart attacks from overexertion, and other secondary impacts that may be difficult to distinguish as weather-related. The NCDC data in the preceding table shows some clear geographic effects in historical snowstorm patterns. One is the lake effect—the table is organized so that "tiers" of counties are listed together, from south to north (and from west to east, within each tier). A dot appears just before the name of the westernmost county in each tier-group, and these counties, which are close to Lake Michigan, can also be seen to have greater snowfall events, and these numbers generally decline from county to county as one proceeds eastward across each tier. Within this 18-year historical average, these counties range from about 7 snowstorm days per year down to only about 2, but these averages show signs of increasing over time, due to increasing precipitation in Michigan. (However, the proportion of this precipitation that falls in the form of snow rather than rain or sleet is trickier to predict.) In parts of the Upper Peninsula, there is an average of up to 11 snowstorms per year.

By observing winter storm watches and warnings, adequate preparation can usually be made to reduce the impact of snowstorms on Michigan communities. Providing for the mass care and sheltering of residents left without heat or electricity, and mobilizing sufficient resources to clear blocked roads, are the primary challenges facing community officials. Severe snowstorms can affect every Michigan community. Therefore, every community should plan and prepare for severe snowstorm emergencies. That planning and preparedness effort should include the identification of mass care facilities and necessary resources such as cots, blankets, food supplies and generators, as well as snow clearance and removal equipment and services. Pre-planning for snow storage areas will be helpful. In addition, communities should develop debris management procedures (to include the identification of multiple debris storage, processing and disposal sites) so that the tree and other storm-related debris can be handled in the most expedient, efficient, and environmentally safe manner possible.

Heavy snows can shut down towns and cities for a period of a few days if snow is persistent and cannot be cleared in a timely fashion. Roof failures may occur as the weight and volume of snow cause damage to homes and buildings. Urban areas are especially susceptible to outages and problems with snow removal, while rural areas may have inaccessible roads for some time but have residents that are more prepared to handle power outages and temporary isolation. Motorists and passengers in cars can be stranded in rural areas and die of exposure because of inadequate preparation for conditions.

Impact on the Public

Snowstorms present hazards that are similar to ice storms, but occur much more frequently. Transportation impairments tend to be of longer duration and require the clearance of snowy "debris" out of the areas needed for transportation or other useful functions. The work required to move accumulated snow (which may "drift" to significant heights or be blown back in place by wintry winds) can often overwhelm the capacities of both individual residents as well as public workers and local budgets.

Impact on Public Confidence in State Governance

For this hazard, the main issues regarding public confidence in government predominantly involve: (1) the ability of the infrastructure of the impacted area to withstand the winter storm event and continue to serve area residents, and (2) the ability of the government(s) to efficiently clear away snow and ice from areas that are most vitally needed for transportation and other shared public uses (e.g. schools, hospitals). If any shortcomings or failures in one or both of these functions are too evident to citizens (or mass media providers), then the capacity, efficiency, and adequacy of government(s) may be called into question. In many areas, the State and different forms of local governments and agencies will have different types of responsibilities, and where problems arise in the coordination or clarity of these governments' actions and responsibilities, discontent can reasonably be expected to be expressed by citizens.

Impact on Responders

Responders are asked to be outdoors during winter weather events in which most citizens prefer to take shelter. In addition to the risks from winds, obscured vision, impaired control of vehicles, power failures and blocked roadways, winter storm events also expose responders to extremely cold temperatures for long periods of time, and may thus compound the difficulties, risks, and expenses of response. Fatigue can more easily become a problem under extreme temperature conditions, either during winter weather emergencies or during extreme summer heat and humidity. Snow can impede facility access and make travel and outdoor activities treacherously slippery.

Impact on the Environment

Heavy snowstorms and severe blizzards can cause environmental impacts. Snowstorms can damage trees, with the weight of heavy snow accumulations bringing down limbs, branches, or entire trees. Dried dead trees more readily catch fire, contributing to wildfires in other seasons if not removed properly. Dead trees can become a breeding ground for beetles or other pests that can harm healthy green trees in non-winter seasons. Animal deaths can occur as a result of immobility, injury, infections, frost bite, hypothermia, etc. Floods often occur when snow melts, and can cause environmental effects (as described in the flooding section). Erosion from melted snow can occur, affecting beaches and soils, and harming vegetation.

Snow can function as a significant source of water pollution since it accumulates a variety of contaminants from the atmosphere and roadways. The removal of snow from roadways can damage the physical and biological environment with contaminants that include salts and salt additives, sediments, metals/emissions, asbestos, petroleum products, bacteria, organic chemicals, soil materials and litter. Those materials that accumulate in roadway-removed snow affect streams, rivers, ground water resources, and lakes, causing harm to fish species and destruction of bottom-dwelling fish fodder. The contamination of soil and groundwater can also result in vegetative stress and decreased productivity. The contamination in sediments can accumulate in the tissues of plants and animals and cause harm.

Climate Change Considerations

The effect of climate change upon Michigan is expected to cause an increase in the amount of precipitation. Even though the length of Michigan winters has been decreasing, the season remains an intense one. During the winter months, the increase in precipitation means that snowfall events will tend on average to be more intense. More snowfall is likely to happen at a time, and thus take the form of significant snowstorm events (e.g. 8 or more inches, higher snowdrifts, cancelled school sessions, etc.).

Historically Significant Snowstorms of General Interest in Michigan and Across the United States

Winter 1888 - Northern U. S.

The fabled Winter of 1888 was devastating to much of the northern United States, with snow, freezing temperatures, and severe winds responsible for the deaths of hundreds of people and thousands of cattle across the Dakota Territory, Minnesota, Wisconsin, and Michigan's Upper Peninsula. As bad as conditions were in the Midwest, however, one single snowstorm will forever characterize that brutal winter. The famous Blizzard of 1888 struck the eastern seaboard on March 12, 1888, dumping 40-50 inches of snow in New York and creating 30-40 foot snowdrifts in parts of southern New England. Snowdrifts were reported over the tops of houses from New York to New England, including some three-story houses. One town in New York had a snowdrift that measured 52 feet in height. Over 400 people died in the blizzard, including 200 in New York City alone. Wind gusts up to 80 miles per hour were reported, which contributed greatly to the tremendous drifting and high number of deaths.

November 7-12, 1913 - Eastern Great Lakes (primarily Lake Huron)

Although severe winter storms on the Great Lakes are common in November, the fall storm of November 7-12, 1913 is considered the greatest ever to strike the Great Lakes. No other Great Lakes storm in modern history compares to the November 1913 storm in terms of death and destruction. The November 1913 storm development was similar to the monster storm that struck Michigan on January 26-27, 1978 (see previous description). Like the 1978 storm, the November 1913 storm was also dubbed a "white hurricane" because of its tremendous size and strength. Winds up to 62 miles per hour and blizzard-like snow struck Port Huron on November 8-9, while in Detroit wind gusts of 70 miles per hour were reported. Port Huron was buried with heavy snow and snow squalls, creating four to five-foot drifts that immobilized the city. The heavy snow pummeled many other shoreline communities as well. On Lake Huron, sailors reported continuous, battering waves at least 35 feet high. The constant barrage of water severely punished various ships and eventually led to their demise. Forty ships were believed to have sunk in that storm, with at least 235 sailors lost. Of the 40 vessels, eight were large lake freighters that went down with all aboard.

More Recent Major Snowstorms in Michigan

January 26-28, 1967 – Mid-Michigan

From January 26-28, 1967 a snowstorm dumped 24 inches of snow in Mid-Michigan, causing Lansing and other area communities to virtually come to a standstill. The storm contributed to 17 deaths across the region. Hundreds of motorists were stranded in their cars and had to be rescued by the National Guard and local law enforcement. The heavy snowfall caused the collapse of roofs on numerous homes and businesses, and shut down public transportation services. Several public shelters were opened to accommodate those stranded by the snow or without heat or electricity due to downed power lines.

January 26, 1977 – Southern Michigan

Beginning on January 26, 1977, a major snowstorm occurred that affected vast portions of southern Michigan. Winds of blizzard proportions resulted in extensive drifting of snow, blocking many roads. Many residents were isolated in rural residences or stranded in public shelters. This storm resulted in a Presidential Emergency Declaration for 15 counties in the southern part of the state.

January 26-27, 1978 – Statewide

On January 26-27, 1978 a severe snowstorm struck the Midwest, and Michigan was at the center of the storm. Dubbed a "white hurricane" by some meteorologists, the storm measured 2,000 miles by 800 miles and produced winds with the same strength as a small hurricane and tremendous amounts of snow. In Michigan, up to 34 inches of snow fell in some areas, and winds of 50-70 miles per hour piled the snow into huge drifts. At the height of the storm, it was estimated that over 50,000 miles of roadway were blocked, 104,000 vehicles were abandoned on the highways, 15,000 people were being cared for in mass care shelters, and over 390,000 homes were without electric power. In addition, 38 buildings suffered partial or total roof collapse. Two days after the storm, over 90% of the state's road system was still blocked with snow, 8,000 people were still being cared for in shelters, 70,000 vehicles were stranded, and 52,000 homes were still without electricity. This storm resulted in a Presidential Emergency Declaration for the entire state, to provide assistance with snow clearance and removal operations.

December 9-12, 1995 – Sault Ste. Marie (Chippewa County)

On December 9, 1995 a snowstorm moved across the Upper Peninsula and stalled near Sault Ste. Marie for nearly 24 hours, dumping a record 28 inches of snow on the city. That eclipsed the city's previous 24-hour snowfall record (15.2 inches, in 1988) by more than one foot. By the time the storm system passed on December 12, Sault Ste. Marie had received a total of 61.7 inches of snow. The excessive snowfall presented a great threat to public safety. Most city streets were impassable to emergency vehicles, and snowdrifts and piles restricted visibility at intersections and buried hundreds of fire hydrants. Schools and most businesses were closed due to the difficult conditions.

A Governor's Emergency Declaration was granted on December 13 to provide assistance with snow clearance and removal activities. The Michigan National Guard was activated, along with work crews from the Michigan Department of Transportation and the Michigan Department of Corrections, to clear and remove snow. (The Guard alone removed more than 150,000 cubic yards of snow in five days.) The Michigan Family Independence Agency and Michigan Office of Services to the Aging provided assistance to senior citizens and other homebound individuals. The Michigan Department of Environmental Quality waived regulations to allow the disposal of clean snow into the St. Mary's River. Other areas that received heavy snowfall in this storm event included Munising with 53 inches, Ontonagon with 43 inches, and Silver City and Houghton with 34 inches.

December 20, 1996 – Southwestern Lower Peninsula

On December 20, 1996 heavy snow rapidly became lake enhanced and dumped storm totals up to 20 inches in the southwestern Lower Peninsula. Schools were closed for up to two days in some areas. Some secondary roads were blocked until road crews could get control of the situation.

January 10-12, 1997 – Western Lower Peninsula

During a three day period from January 10- 12, 1997 heavy snow was reported in Ottawa and Kent County for all areas of snowfall of at least 12 inches or more. In neighboring Allegan County the snow was measured at 28 inches on Friday evening and 40 inches by Saturday afternoon. In the northern portion of the Lower Peninsula, Grand Traverse County received 12 to 18 inches. Schools were used as emergency shelters for stranded motorists throughout the affected area. Secondary roads across all of the area were blocked from Friday night into Saturday and interstates were also closed for a few hours late Friday into Saturday. Accidents occurred at the rate of 50 to 100 per county per day from the 10th through the 12th.

March 13-15, 1997 – Upper Peninsula

Beginning on the afternoon of March 13, 1997 and continuing until the morning of March 15, a snowstorm moved across the Upper Peninsula, dumping 20-30 inches of heavy snow in many communities. Although the Upper Peninsula is accustomed to heavy snows throughout the winter, this storm produced snowfall totals that were significant even for that region. In Marquette, nearly 33 inches of new snow fell. In a 24-hour period between March 13-14, Marquette received 28 inches of snow, breaking the 24-hour snowfall record set back in March 1986. The storm also produced a record snow depth of 63 inches at Marquette County Airport, eclipsing the previous record of 59 inches recorded in March 1976. The storm dropped 29 inches of snow at Phoenix in Keweenaw County, 25 inches at Herman in Baraga County, and 21 inches at Shingleton in Alger County. Numerous other communities across the region received between 16 and 20 inches of new snow.

October 26-27, 1997 – Southern Lower Michigan

An early season snowstorm crossed southern Lower Michigan on October 26, 1997, dumping 2-8 inches of heavy, wet snow. Because of the significant amount of foliage still left on the trees, the added weight of the heavy snow caused many trees and tree branches to break, resulting in numerous power outages and reports of property damage from downed trees. At the height of the storm, over 330,000 electrical customers statewide were left without power – 195,000 in the Grand Rapids area alone. Total property damage was estimated at $1.2 million. Because of the widespread power outages (some of which lasted 36-72 hours), shelters were established in several communities to care for senior citizens and others vulnerable to the cold. The storm forced the closure of many schools and businesses throughout the impacted area.

January 2-3, 1999 – Southern Lower Peninsula

In the early morning hours of January 2, 1999 a severe winter storm moved across the western and southern portions of Michigan. The storm grew in intensity and size, producing record or near-record snowfall that affected much of the southern two-thirds of the Lower Peninsula by the late evening hours of January 3. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on January 4 in some areas. Subsequent storms over the next several days dumped an additional foot of snow in many areas of the state, resulting in snowfall of historic proportions in several Michigan communities. Combined, these winter storms produced the worst winter conditions to hit Michigan since the statewide blizzard that occurred in January 1978 (see description above).

The effects of the blizzard on the city of Detroit were the focus of national media attention. Detroit and surrounding communities received nearly two feet of snow during the blizzard. The unusually intense snowfall, coupled with the frigid temperatures and blowing and drifting snow, severely hampered snow removal operations within Detroit. The City's inability to plow residential streets created public health and safety concerns in many areas due to lack of access for police, fire, and other emergency vehicles. The unplowed streets and sidewalks also forced the Detroit school system to close for several days, idling more than 180,000 students. The heavy snowfall collapsed numerous commercial building roofs in Detroit and throughout southeast Michigan. In addition, ice dams on residential roofs were a widespread problem, damaging tens of thousands of structures. The record snowfall also hampered mail delivery, affected the ability of residents to travel to and from work, and negatively impacted business activity and tourism.

At Detroit Metropolitan Airport, the severe winter conditions forced the cancellation of hundreds of flights over the three-day period from January 2-4, stranding thousands of travelers without adequate accommodations. Numerous planes landed at the airport, only to sit on the runway apron for hours at a time – unable to unload passengers because the snow could not be cleared from the gates fast enough or there simply were not enough open gates or personnel to handle the large influx of planes. This situation also drew the attention of the national media and cast a negative shadow over the airline and airport operations. A Presidential Emergency Declaration was granted for the 31 Michigan counties that received record or near-record snowfall, making available Federal snow removal assistance under the Federal Emergency Management Agency's (FEMA) Public Assistance Grant Program.

January 12-14, 1999 – Southeastern Lower Peninsula

Large snowfall amounts caused difficulty in finding places to store the snow. Roofs collapsed under the weight of the snow and especially caused expensive damage to a shopping center and numerous businesses across the metropolitan area. Ice dams caused many leaking roofs (estimated in the tens of thousands), including damage to rare documents in the Clements Library of the University of Michigan in Ann Arbor. Estimated direct property damage amounted to $950,000 in Wayne County and $350,000 in Oakland County (plus three injuries), but these figures obviously do not include the problems from all the ice dams on roofs.

November 20, 2000 – Southwestern Lower Peninsula

On November 20, 2000 the first snow storm of the season for the Grand Rapids area produced a record 24 hour snowfall of 11.5 inches at the National Weather Service in Grand Rapids, breaking the old record of 10.4 inches. Lake effect snow continued through the night and during the morning hours of the 21st, and 1 to 2 feet of snow fell across parts of Ottawa County. Allegan County also received 24 inches.

December 11-31, 2000 – Central and Southern Lower Peninsula

In the early morning hours of December 11, 2000 a severe winter storm moved through the state, inflicting its heaviest effects on the southern two-thirds of the Lower Peninsula before moving out of the state on the morning of December 12. That storm produced record or near-record 24-hour snowfall levels in 31 counties, paralyzing the entire region. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on December 13 in some areas. The storm produced great hardships for many Michigan communities. Schools across much of southern Lower Michigan were closed for several days, the storm forced the cancellation of hundreds of airline flights in and out of Detroit Metro Airport and at other airports across the region, and many businesses were forced to close at the height of the Christmas shopping season (the most profitable shopping period of the year). Damage in Genesee County was estimated at $1.1 million, as the roof of a manufacturing company collapsed and injured one person. During the storm, up to 200 cars were stranded on I-75 south of Flint. A Richmond home burned down because firefighter vehicles were unable to reach it. Around Caro (Tuscola County), 41 automobile accidents took place, including an 18-car pile-up that required snowmobiles to respond to. 16.3" of snow had fallen around Caro.

Another series of winter storms the following week dumped an additional foot or more of snow across southern Lower Michigan, increasing snow depths in many counties to two feet or more. The tremendous snow depths caused a host of public health and safety concerns across the region. The snow fell at such a steady rate in many areas that public works crews worked at maximum capacity – often around the clock – for two weeks just to keep pace. The weight of the accumulated snow caused numerous collapsed roofs on homes and businesses, and ice dams and water seepage damaged thousands of structures well into January 2001. In addition, several house fires erupted when water from melting snow and ice seeped into electric meter boxes.

The cumulative effects of the heavy snowfall, high winds, and severe cold temperatures that began on December 11 caused problems across the region for the next several weeks. The sheer volume of snow made it difficult to handle, and the process of clearing it out of the way became difficult and expensive, as there was almost no place to put it. Many communities used the majority of their annual snow-removal budget and their road salt supply to combat these storms. The winter storms of December 2000 produced the worst winter conditions to hit Michigan since the statewide blizzards that occurred in January 1978 and January 1999. In Flint and Saginaw, the December 2000 snowfall set an all-time record for ANY month. In many other areas, it set all-time records for the month of December.

A Presidential Emergency Declaration was granted for the 39 Michigan counties that received record or near-record snowfall or incurred significant cumulative effects, making available Federal snow removal assistance under the Federal Emergency Management Agency's (FEMA) Public Assistance Grant Program.

January 5, 2001 – Livingston and Oakland Counties

Three persons were injured in Brighton when the weight of accumulated snow caused an awning-style roof to collapse along the edge of a warehouse ($75,000 damage). Later in the day, a man died in Waterford Township by falling from his roof while trying to shovel snow from it.

December 23-29, 2001 – Southwestern and Northern Lower Peninsula

From December 23-29, 2001, Grandville (in Kent County) received 26 inches of snow. Up to 15 inches of snow fell in Grandville in less than 24 hours and around 24 to 26 inches of snow fell total in a band from Ottawa County southwest to Allegan County. Even more lake effect snow redeveloped on the 28th and continued through the 29th, producing additional snowfall of 8 to as much as 22 inches across the area. 12 to 18 inches of snow was common across the Grand Rapids area. There was also a narrow strip of around a foot of snow that fell about 25 miles inland from Ottawa county.

Storm total snowfalls broke all previous records for snowfall in one week in several locations across southwest Michigan. Grandville (Kent County) ended up with 70.2 inches of snow for the week, which was the greatest reported snowfall total across the area. The National Weather Service Forecast Office in Grand Rapids (Kent County) had a storm total snowfall of 50.6 inches for the week. Generally speaking, the heaviest snow accumulations for the week occurred along the US-131 corridor from Grand Rapids down through Allegan County, where two to four feet of snow fell. The cities of Petoskey and Charlevoix broke their 2 and 3 day snowfall total records with amounts of 44 and 60 inches and 27 and 39 inches, respectively. Traverse City tied their 2 day snowfall record with 20.5 inches from the 28th through the 29th. Many other areas saw snowfall totals of a foot or more during the last week of December.

January 29-30, 2002 – Southern Lower Michigan

Severe winter weather battered much of the Lower Peninsula for two days during the end of January 2002, bringing a foot or more of snow, mixed with sleet and ice. Schools were closed, roads were flooded, and over 152,000 were left without power. Four people were killed in weather-related traffic accidents in Kent, Saginaw, Midland, and St. Joseph Counties. AAA Michigan served more than 2,850 motorists by the late afternoon on January 30. Detroit Metropolitan Airport cancelled more than 170 departures and 183 arrivals due to weather conditions.

March 2, 2002 – Lower Michigan Peninsula

On March 2, 2002 a winter storm produced heavy snow across most of the Lower Peninsula, producing 12 to 18 inches of snow. The maximum snowfall reported was in Ludington (Mason County), where 18 inches of snow fell. The snow was particularly wet and heavy, and numerous tree limbs and power lines were downed in the area.

February 7 and 12, 2003 – Southwestern Lower Michigan

On February 7, 2003, blizzard conditions caused a 72-car accident on I-94 in Benton Township (Berrien County). The accident began when a car slid under the back of a semi-tractor trailer during whiteout conditions. Those involved in the crash stated that the heavy lake-effect snow had reduced visibility and caused poor road conditions. When the motorists approached the I-94 and I-196 interchange, the weather changed from bad to worse, causing zero visibility. These conditions caused cars to slow at different rates, and thus a chain collision ensued.

Only five days later, on February 12, 2003 an Alberta clipper moved through and produced heavy snow across western Lower Michigan. The heaviest snowfall report was received from Walker (Kent County), where 14 inches of snow fell. A large swath of anywhere from 6 to 10 inches of snow fell across other parts of Ottawa County as well as Kent County. There were also localized reports of a foot or more of snow received in the two counties.

January 19-20, 2004 – Northwestern Lower Peninsula

Heavy lake effect snow came in off of Lake Michigan, accompanied by gusty northwest winds and blowing and drifting. The most persistent band of snow settled in from central Leelanau County to western Grand Traverse County. Around 20 inches of snow fell near Interlochen, with drifts of 5 to 6 feet across M-72 in Leelanau County.

January 27, 2004 – Central Lower Michigan

On January 27, 2004, six to ten inches of snowfall occurred across much of central Lower Michigan. Up to 14 inches of snow accumulated northeast of Grand Rapids, in Montcalm County. Visibility was near zero when a pileup involving about 50 cars and trucks occurred on I-96 near Portland, shutting down both sides of the highway. There was only one injury reported and the highway was reopened about three hours later. Police in the tri-county area had responded to more than 200 accidents during the day.

November 24-25, 2005 – Northern Lower Peninsula

Lake effect snow quickly developed and became intense by the afternoon of Thanksgiving Day throughout much of the northern portions of the Lower Peninsula. Near-blizzard conditions developed, with wind gusts of 25 to 35 mph inland and 50 mph near the coastlines, lowering visibilities to near zero at times. Total snowfall amounts of 12 to 18 inches were common in the prime snow belts regions around Gaylord, Kalkaska, and Mancelona. Holiday travel was impacted severely by the falling, blowing, and drifting snow. Numerous accidents occurred on area highways.

February 3-4, 2007 – Southwest Lower Michigan

The combination of lake-effect snow (and snow already on the ground) with very strong winds resulted in blizzard conditions across western Lower Michigan on February 3rd. The maximum snowfall total for a twelve hour period was eight inches, and the maximum snowfall total for a 24-hour period was 12 inches. The highest snowfall total for the entire event was 17 inches, in Grandville. The Gerald R. Ford International Airport in Grand Rapids reported visibility at or under a quarter-mile from 9:30 a.m. through 8 p.m. on Saturday February 3rd. Numerous other observation sites across far western Lower Michigan also reported blizzard conditions. Many locations reported sustained winds of 20 to 30 mph, with gusts to around 40 mph, during the late morning and afternoon hours of the 3rd. The blizzard conditions resulted in numerous road closures, power outages, and car accidents.

February 25-26, 2007 – Northern Lower Peninsula

A low pressure system stalled out over the Southwest Great Lakes region resulting in a fairly extensive period of accumulating snowfall and gusty east winds in much of Northern Lower Michigan. The axis of heaviest snowfall stretched from Cadillac to Lake Ann, with total of 12 to 15 inches. Blustery winds produced considerable blowing and drifting snow. Wexford County officials reported that more than 50 vehicles slid off of area roads. Numerous schools were closed on the 26th.

February 6-7, 2008 – Saginaw County

Widespread heavy snowfall of 8 to 12 inches occurred along and north of the I-69 corridor in eastern Michigan. The heaviest snow total of 16 to 18 inches occurred in Saginaw County. This snowstorm total in Saginaw County was the biggest amount since the Blizzard of 1978. Strong northeast winds off of Saginaw Bay also led to near blizzard conditions. Road crews in Saginaw County could not keep up with the snow, which fell at a rate of 2-4 inches per hour. Two to three foot snow drifts left at least 50 cars stranded. Snowfall amounts tapered off south of I-69, as sleet mixed in, cutting down accumulations quickly, with less than 3 inches across Wayne County and points to its south.

February 10, 2008 – Southwest Michigan

A blizzard event involved a combination of extreme cold, frequent wind gusts up to 40 mph, whiteout conditions, heavy snow, and blowing snow. There was a fifty-car pileup on I-196 in Ottawa County, causing 20 persons to receive treatment for minor injuries. Snowfall totals were the greatest over Allegan and Van Buren Counties. Snow drifts of 3 to 5 feet deep were common in rural areas. Property damage was estimated at $250,000 in Ottawa County.

December 21-22, 2008 – Western Lower Peninsula

From December 21-22, 2008 six to 12 inches of snow fell in Kent and Ottawa Counties, accompanied by wind gusts up to 45 mph. This resulted in two to three foot snow drifts across portions of the area. In conjunction with the blizzard to near-blizzard conditions, this produced dangerous travel conditions. Farther north, Wellston ended up with 23 inches of snow in 24 hours, and many Northern Lower Peninsula areas received similar amounts. At the height of the storm, several stretches of highway were shut down due to multiple vehicle accidents.

December 3-4, 2009 – Grand Rapids Area

From December 3-4, 2009 over a foot of snow was reported across portions of Ottawa County, where 15 inches fell in Marne and 14 inches fell in Coopersville. Several inches of slushy snow accumulated on roads from Muskegon to Grand Rapids. The following week, four to eight more inches of snow, in conjunction with wind gusts to 40 mph, created near-blizzard conditions at times, resulting in very hazardous travel conditions. Numerous accidents were reported, due to slippery roads and reduced visibility in the blowing snow.

December 9-11, 2009 – Northern Lower Peninsula

From December 9-11, 2009 heavy snowfall totals and blizzard conditions were common across all of Northern Michigan. The snow transitioned to lake effect snow that night, and lasted into the 11th in some of the snow belts. Gaylord had its 2nd largest three-day snowfall since 1950, with 21.8 inches. There was a considerable amount of wind, with some gusts over 50 mph, causing blowing and drifting snow. Almost all school districts were closed on the 9th, and some schools called off classes for three consecutive days. Numerous accidents were reported, due to slippery roads and reduced visibility in the blowing snow.

February 9-10, 2010 – Ottawa County

From February 9-10, 2010 six to ten inches of snow fell across Ottawa County. The storm coincided with Michigan's winter “Count Day,” used to determine base funding for local public school systems. Many school systems closed due to the snowstorm. Several significant accidents occurred on the region’s primary arteries. I-94 was closed for several hours, due to jackknifed trucks. There was also a multiple vehicle pileup on I-196.

February 1-2, 2011 – Southern Lower Peninsula

From February 1-2, 2011 a major winter storm occurred throughout much of Lower Michigan. The storm brought 10 to 15 inches of snow and blizzard conditions to much of southern Lower Michigan. Wind gusts in excess of 40 mph combined with heavy snow to produce whiteout conditions and snowdrifts of 3 to 5 feet. Thunder accompanied the snow in some areas with snowfall rates exceeding two inches per hour. Many businesses, schools (including major universities), and some government offices were closed the next day. Most main roads were plowed by the next day but some side streets were not cleared for a couple more days.

November 29-30, 2011 – Central Southern Lower Peninsula

A snowstorm dumped 8 to 10 inches of snow across multiple counties in central Michigan. The heavy wet snow, plus strong winds, caused many trees, limbs, and power lines to fall, leaving 30,000 persons without power. Numerous traffic accidents occurred, and a gas station awning collapsed in Haslett (Ingham County) under the weight of the snow. Property damages totaled $1 million in each of the following counties: Jackson, Calhoun, Ingham, Eaton, and Clinton. In Eaton County, two fallen trees partially blocked Billwood Highway in Windsor Township.

March 2-3, 2012 – Northern Lower Peninsula (Leelanau, Benzie, and Grand Traverse Counties)

A high-impact snowstorm brought snowfall totals that ranged from 6 to 14 inches across most of Northern Michigan, with higher amounts in some areas and a maximum of 20 inches near Lake Ann (Benzie County). The snow was very wet and heavy, causing many trees and power lines to fall. Power outages were widespread, and the majority of Northern Michigan residents lost power at some point during or after the storm, sometimes for as long as a week. In Benzie County, 95% of residents lost power, property damages totaled $600,000, and crop damages totaled $2 million. In Grand Traverse County, $600,000 in property damage was done, along with $5 million in crop damage. Substantial damage was done to fruit trees, especially cherry trees. In Leelanau County, $650,000 in property damage and $13 million in crop damage was reported. Many communities opened shelters, to aid those whose homes had no power or heat.

Winter of early 2014 – Michigan

Although the winter events are still occurring at the time of this writing, and therefore are too new to summarize, it is clear that the winter has been an unusually challenging one. Roadway sections across the state were left in poor condition by the effects of a series of thaws and re-freezes during early winter. In addition to below-average temperatures (see the extreme temperatures section), an above-average amount of snowfall gave many Michigan communities trouble in clearing roadways and finding places to store the snow. The heavy snows followed a damaging ice storm that left many households without power. Hundreds of traffic accidents took place during icy and blizzard conditions. The next edition of the Michigan Hazard Analysis will contain a full summary of the season’s events.

Programs and Initiatives

Note: Many of the programs and initiatives designed to mitigate, prepare for, respond to, and recover from ice and sleet storms have the dual purpose of also protecting against snowstorms. As a result, there is some overlap in the narrative programs and initiatives descriptions for each respective hazard. This redundancy allows each hazard section to stand alone, eliminating the need to refer to other hazard sections for basic information.

National Weather Service Doppler Radar

The National Weather Service has completed a major modernization program designed to improve the quality and reliability of weather forecasting. The keystone of this improvement is Doppler Weather Surveillance Radar, which can more easily detect severe weather events that threaten life and property – including severe winter weather events such as snowstorms. Most importantly, the lead time and specificity of warnings for severe weather have improved significantly.

National Weather Service Watches, Warnings and Advisories

The National Weather Service issues winter storm watches and winter weather warnings to notify the public of severe winter weather conditions. A winter storm watch indicates that severe winter weather conditions (freezing rain, sleet, or heavy snow) may affect an area, while a winter weather warning indicates that severe winter weather conditions are imminent.

Winter storm warnings can be issued for snow alone, but they can also take on different varieties. For example, a blizzard warning signifies that blizzard conditions are imminent or occurring. Blizzard conditions mean that the visibility will frequently be one-quarter mile or less in falling or blowing snow, with wind speeds of at least 35 miles per hour. A wind chill warning is issued when wind chills drop below -30 degrees Fahrenheit, with winds equal to or greater than 10 miles per hour. Finally, an ice storm warning is issued for a significant accumulation of ice, normally a coating of at least one-quarter inch.

The National Weather Service also issues a number of different advisories for winter weather. These advisories can be issued for snow, freezing rain, blowing snow, and wind chill, among other things. Advisories mean that conditions are expected to cause significant inconveniences and may be hazardous. However, if caution is exercised, the situation should not become life threatening.

The State and local government agencies are warned via the Law Enforcement Information Network (LEIN), National Oceanic and Atmospheric Administration (NOAA) weather radio, and the Emergency Managers Weather Information Network (EMWIN). Public warning is provided through the Emergency Alert System (EAS). The National Weather Service stations in Michigan transmit information directly to radio and television stations, which in turn pass the warning on to the public. The National Weather Service also provides detailed warning information on the Internet, through the Interactive Weather Information Network (IWIN).

Winter Hazards Awareness Week

Each fall, the Emergency Management and Homeland Security Division, Department of State Police, in conjunction with the Michigan Committee for Severe Weather Awareness, sponsors Winter Hazards Awareness Week. This annual public information and education campaign focuses on winter weather hazard events such as snowstorms, blizzards, extreme cold, and ice and sleet storms. Informational materials on winter weather hazards and safety are disseminated to schools, hospitals, nursing homes, other interested community groups and facilities, and the general public.

Electrical Infrastructure Reliability

One of the major problems associated with any winter weather hazard (including snowstorms) is the loss of electric power. Although the problem is not quite as chronic in Michigan as it is with ice storms, snowstorms have nonetheless caused several widespread and severe electrical power outages. Weather-related damage to electric power facilities and systems is a concern that is being actively addressed by utility companies across the state. Detroit Edison, Consumers Energy and other major electric utility companies have active, ongoing programs to improve system reliability and protect facilities from damage by snow, ice, severe winds, and other hazards. Typically, these programs focus on trimming trees to prevent encroachment of overhead lines, strengthening vulnerable system components, protecting equipment from lightning strikes, and placing new distribution lines underground. The Michigan Public Service Commission (MPSC) monitors power system reliability to help minimize the scope and duration of power outages.

Urban Forestry/Tree Maintenance Programs

Urban forestry programs can be very effective in minimizing snowstorm damage caused by falling trees or tree branches. In almost every severe snowstorm, falling trees and branches cause power outages and clog public roadways with debris. However, a properly designed, managed and implemented urban forestry program can help keep tree-related damage and impact to a minimum. To be most effective, an urban forestry program should address tree maintenance in a comprehensive manner, from proper tree selection, to proper placement, to proper tree trimming and long-term care.

Every power company in Michigan has a tree trimming program, and numerous local communities have some type of tree maintenance program. The electrical utility tree trimming programs are aimed at preventing encroachment of trees and tree limbs within power line rights-of-way. Typically, professional tree management companies and utility work crews perform the trimming operations. At the local government level, only a handful of Michigan communities have actual urban forestry departments or agencies. Rather, crews from the public works agency or county road commission perform the bulk of the tree trimming work.

When proper pruning methods are employed, and when the work is done on a regular basis with the aim of reducing potential storm-related damage, these programs can be quite effective. Often, however, tree trimming work is deferred when budgets get tight or other work is deemed a higher priority. When that occurs, the problem usually manifests itself in greater storm-related tree debris management problems down the line.

Mitigation Alternatives for Snowstorms

- Increased coverage and use of NOAA Weather Radio.
- Tree trimming and maintenance to prevent limb breakage and safeguard nearby utility lines. (Ideal: Establishment of a community forestry program with a main goal of creating and maintaining a disaster-resistant landscape in public rights-of-way.)
- Buried/protected power and utility lines. (NOTE: Where appropriate. Burial may cause additional problems and costs in case of breakage, due to the increased difficulty in locating and repairing the problem.)
- Establishing heating centers/shelters for vulnerable populations.
- Proper building/site design and code enforcement relating to snow loads, roof slope, snow removal and storage, etc.
- Agricultural activities to reduce impacts on crops and livestock.
- Pre-arranging for shelters for stranded motorists/travelers, and others.
- Using snow fences or "living snow fences" (rows of trees or vegetation) to limit blowing and drifting of snow over critical roadway segments.

Tie-in with Local Hazard Mitigation Planning

Because many means of implementing mitigation actions occur through local activities, this updated MHMP places additional emphasis on the coordination of State-level planning and initiatives with those taking place at the local level. This takes two forms:

1. The provision of guidance, encouragement, and incentives to local governments by the State, to promote local plan development (including a consideration of snowstorms), and
2. The consideration of information contained in local hazard mitigation plans when developing State plans and mitigation priorities.

Regarding the first type of State-local planning coordination, the information immediately following provides advice regarding the snowstorm hazard to offer guidance to local planners, officials, and emergency managers. It has been adapted from the February 2003 “Local Hazard Mitigation Planning Workbook” (EMD-PUB 207). For the second type of State-local planning coordination, a section follows that summarizes snowstorm information as it has been reported in local hazard mitigation plans. For a brief summary of snowstorm-related information from that section of this plan, it will here be noted that snowstorms were identified as one of the most significant hazards in local hazard mitigation plans for the following counties: Counties Reporting Snowstorms as one of their top hazards: Alger, Allegan, Alpena, Antrim, Baraga, Barry, Benzie, Berrien, Branch, Calhoun, Cass, Charlevoix, Cheboygan, Chippewa, Clinton, Delta, Emmet, Genesee, Gogebic, Grand Traverse, Gratiot, Hillsdale, Huron, Isabella, Jackson, Kalamazoo, Kalkaska, Kent, Keweenaw, Lake, Lapeer, Leelanau, Lenawee, Macomb, Manistee, Marquette, Mason, Menominee, Midland, Missaukee, Monroe, Montmorency, Muskegon, Newaygo, Oceana, Ogemaw, Oscoda, Otsego, Ottawa, Roscommon, Saginaw, Schoolcraft, Shiawassee, Tuscola, Van Buren, Wexford. (56 counties).